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Land Use and Traffic Models:

A Progress Report

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PRESIDENTIAL MESSAGE

Challenge and Response

NEVER BEFORE in the history of this nation have planners faced a greater challenge and opportunity than they do today. The past decade has witnessed a tremendous change in the nation's physical development and the inauguration of vast programs requiring sound planning at all levels of government—local, state, and national. The multibillion-dollar national highway program, the rapidly expanding urban renewal program, proposed programs for airport development, the provision of more adequate educational facilities, and the relief of economically distressed areas—all present a challenge which our profession must somehow meet.

Ten million new homes will be constructed during the next eight years, the equivalent of more than three thousand complete residential neighborhoods of one square mile each. If past and present trends continue, many of these homes will be built in scattered and fragmented areas often without benefit of comprehensive planning and creative community design. But they *will* be built—along with many new shopping centers, schools, churches, libraries, recreation centers, office buildings, and factories.

The Rockefeller brothers report on urban renewal needs, estimates that by 1964 seven billion dollars will be required each year to cure the blight of the central cities—a program so vast as to be without precedent.

The scale of new metropolitan expansion into the countryside and the magnitude of rebuilding of vast areas near the urban centers indicate that within another twenty years sixty per cent of all physical improvements in urban areas will consist of *new* buildings—buildings that do not exist today.

What does this vast program imply for the planner? In the decades to come the real test will be whether he has the technical competence, the practical experience, and the creative vision commensurate to the scale of future urban growth. His numbers are greater than ever before and are growing with each passing year. His experience is expanding in proportion to the magnitude of responsibility assigned to him. His education is improving as more and more universities respond to the need for formal planning education and as urban research activity expands.

In what respects has the planner advanced during the past decade? Collaborating with the land economist, he has made great strides in enlarging his technical knowledge of the economic causes and effects of urban development and redevelopment. The planner and the urban sociologist have been working ever more effectively to understand urban cultures and to gain community participation in the decision-making process. The physical planner is rapidly improving his knowledge of planning standards.

Together with the other design professionals—architect, landscape architect, civil engineer, transportation engineer, and others—the planner faces a great challenge in urban design. In response to the tremendous opportunity and responsibility inherent in the expansion and rebuilding of our cities today, master builders will emerge who will understand and love cities and who, steeped in the richness of past cities, will intuitively and selectively perceive those qualities of the past which have true meaning for the present and the future.

If there is one area in which planners require far greater knowledge and experience, it is in the development of effective methods to insure the realization of a sound metropolitan structure and design. Planners must find a way to prevent the coalescence of vast urban regions with resulting loss of open land. As yet there is all too little evidence of effective controls to guide the over-all metropolitan structure. The planner must work with the specialist in government to find the answer to this question. Neither can find the answer alone.

The American Institute of Planners will soon add special workshop groups assigned to study and report on the reservation of open space in metropolitan areas, the financial problems in achieving metropolitan and city plans, and the broad problem of urban design in all its aspects. These, together with conclusions on major policy questions under intensive study by the Institute at the present time, will contribute toward the greater competence of the profession.

The planning profession today is aware of its great responsibilities and is steadily growing in stature and respect. The American Institute of Planners is in a unique position to contribute to the improvement of our nation through increasing the knowledge and effectiveness of its members.

CHARLES A. BLESSING
President
American Institute of Planners

Land Use and Traffic Models

A Progress Report

EDITOR'S PREFACE

DURING THE PAST few years an extremely promising line of inquiry has been hotly pursued by certain city planners, transportation engineers, and social scientists. Their findings promise a more intimate understanding of how our cities are spatially organized and how they operate. This research has also helped to demonstrate that the similarities among cities are greater than their differences and that, despite superficial idiosyncracies, cities exhibit striking regularities of form and function. We are now learning a great deal about these regularities and are quickly moving to the time when we shall be able to describe them in firm theoretical formulations.

A growing excitement of discovery marks this tantalizing research, and for many it has taken on the appearance of the path to the city planner's green pasture. But the real excitement is this: as we learn more about the constraining consistencies of urban form and function—and then perhaps about the underlying reasons for these consistencies—we shall be better able to identify the real range of future choice. If we can understand the limitations upon public choice, we can better identify the real opportunities for deliberately influencing the forms of our future cities. And, as we narrow the margins of uncertainty, we can make more responsible recommendations to the political decision-makers whom we serve.

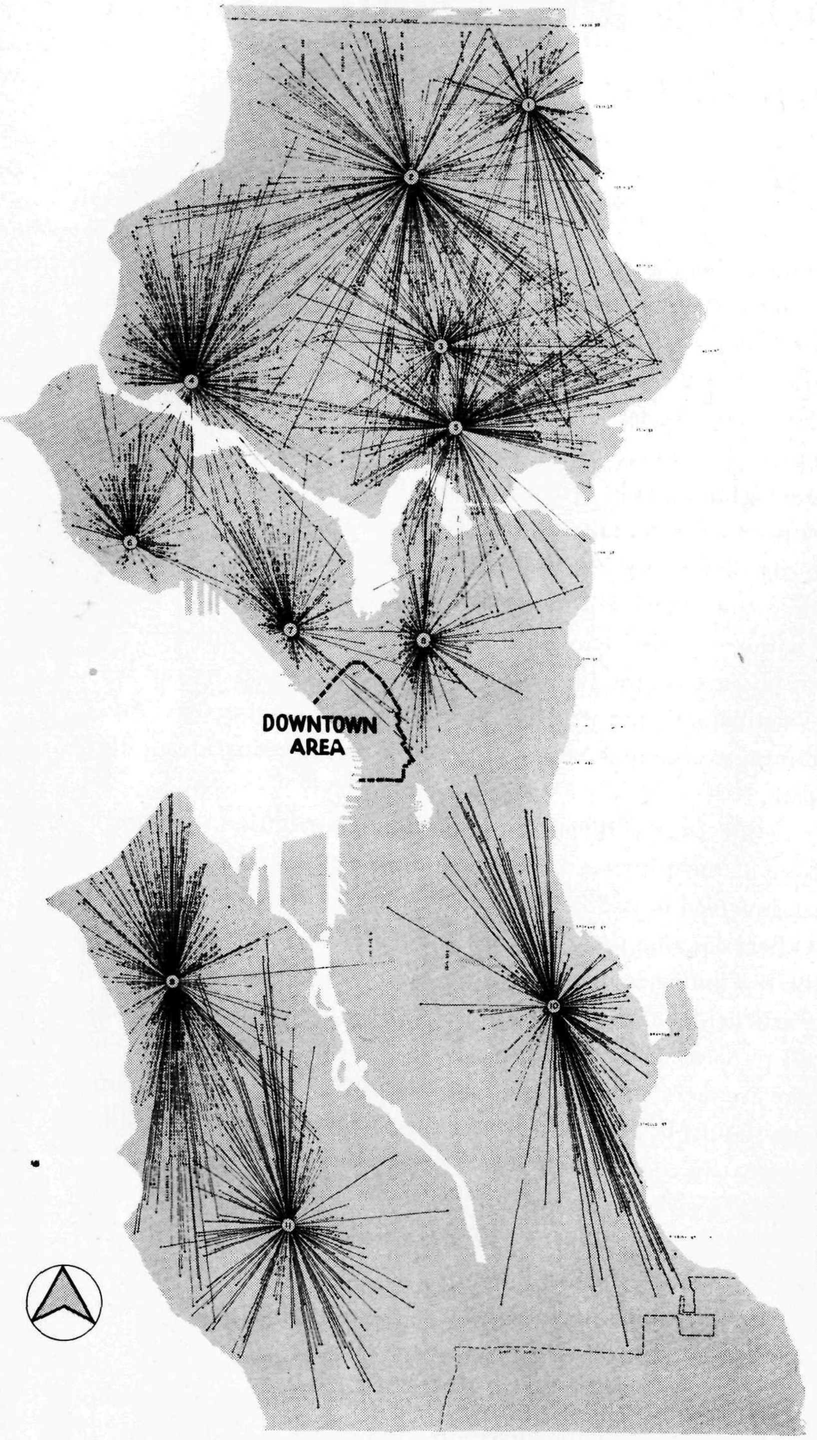
Because we're confident that this recent work will yield an important contribution to the profession's body of theory this entire issue of the JOURNAL is devoted to an early report by several practitioner-researchers who have been involved in it. Some of the contributors describe their early efforts to forecast land use patterns. Others describe their findings about the influence of land use upon traffic patterns and, reciprocally, the influence of transportation facilities on travel patterns and in turn on land use patterns. The article that cannot yet be written will describe the interrelated net of mutual relationships among all parts of the spatial-physical city.

The "models" that are described here are merely *de*scriptive not *pre*scriptive. The authors, humbly, do not suggest what policy choices should be pursued—what kinds of cities are most desirable. But they can help us to identify the alternative cities we might seek. And they can tell us something about our chances of success in pursuing the various cities of our dreams.

This is the real value of their work. In a working alliance with the creative designer, the mathematically sophisticated analyst is learning to test the feasibility of design innovations that no computer can conceive. Here, then, is the embryonic beginning of an analytic approach that will help to provision the city planner's sparsely equipped kit-bag of theory.

This preliminary report to the profession has been prepared under the direction and editorship of Alan M. Voorhees. We gratefully acknowledge his important contribution. We are also grateful to the Automotive Safety Foundation for making his time and that of others of its staff available.

M. M. WEBBER



The choice of shopping centers by Seattle residents shows a very consistent pattern. It suggests certain regularities in land use pattern and in traffic behavior. This issue of the JOURNAL is devoted to an analysis of such regularities and to the relationships among them. The contributing authors explain how they have applied knowledge of these consistencies to improve the plans that their agencies have prepared.

ALAN M. VOORHEES

The Nature and Uses of Models in City Planning

AS THE CITY PLANNING profession matures, the need for revision and improvement of professional techniques is increasingly evident. This need, of course, is not peculiar to city planning; it exists also in the other disciplines. The medical profession, for example, carries on constant experimentation to improve techniques for the diagnosis and cure of disease; the social sciences, to cite another example, have wrought vast changes in interview methods.

City planning has not let the need for technical improvement go unrecognized. Tremendous progress is seen in many aspects of planning, particularly for land use and transportation.

The usual procedure of preparing land use and transportation plans by analyzing facts on population distribution, employment, economic factors, social patterns, and travel habits is yielding to more precise techniques of evaluation. These more accurate techniques are based on research—research indicating that people are predictable, that mathematical formulas can be developed to express travel behavior and to forecast land patterns. Such tools can give valuable guidance in the analysis and design phases of city planning.

Equipped with these techniques, a planner should be able to predict fairly accurately the consequence of varied governmental policies on land development. With them he has the means to evaluate the impact that improved transportation services, extension of sewer and water systems, zoning laws, etc., will have on land development. Also, these techniques make it possible for the planner to estimate traffic volumes and patterns resulting from different arrangements of land use or from various transportation solutions.

Ideally suited for land use and traffic forecasting, such mathematical techniques provide the planner with quantitative results. Using them he can estimate the number of people who will live in an area or the number of trips that will start from a district—valuable information in laying out parks, schools, and highways. *In brief, these procedures provide better data upon which to base planning judgment and thus help to improve the quality of plans.*

These mathematical techniques involve several steps, equations, and formulas, and are often referred to as *models*. More simply, a model may be described as a mathematical statement of observed relationships. For example, one specific model, a by-product of many shopping-habit analyses, has been developed to describe the number of shopping trips that people make. With facts on individual residence, on travel time to shopping centers and on their sizes, an estimate can be made of where consumers do their shopping. The degree of consistency of shopping patterns is shown on the opposite page. Since this model deals with travel habits, it is termed a "traffic model," as are others like it.

In addition to these models, so-called "land use models" are used to calculate changes in land use patterns as a city grows, as new public improvements are provided, or as other public policies are enacted. With a land use model, it should be possible, for instance, to estimate the *size* and *location* of new shopping centers.

To summarize, "land use models" deal with the relationships of land use development, while "traffic models" describe traffic patterns. JOURNAL authors for this special edition have contributed fundamental information about the models which are designed to aid prac-

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Mr. Voorhees is special editor for this issue of the JOURNAL.

titioners in devising better land use and transportation plans.

Models and the Planning Process

Let us now explore mathematical models and their place in the planning process, taking a hypothetical example. A planning commission has prepared an economic projection for its community for 1980. The study indicates certain increases in population and employment. Founded on these predicted increases, a land use model could be used to estimate likely distribution of the population and employment by 1980, that is, if present trends continue, and assuming that no effort is made to change the trends. (A procedure similar to that outlined by Hamburg and Creighton may be employed.) In devising the land use plan, these estimates should be evaluated in the light of over-all community goals and against social-economic factors. On the basis of this plan and with a model similar to that described herein by Booth and Morris, it would be possible to estimate the resulting traffic patterns. Traffic patterns could then be evaluated to determine requirements for highway and public transit facilities.

To find the most feasible public improvements, several transportation alternatives may be studied. A forecast of traffic volume could be "assigned" to the various transportation alternatives. With the implications that could be drawn from these studies and from other city planning factors, a specific transportation network could be selected. After its selection, an additional analysis of the land use plan should be made. A technique such as that discussed by Walter Hansen could be used to determine the manner in which the community is likely to grow if the proposed transportation network follows a certain timetable.

Several construction priority programs might be studied to see which program would contribute the most toward carrying out the objectives of the land use plan. These studies might even prompt the re-evaluation of the original land use plan. If land use is adjusted, the transportation system would have to be reanalyzed since any change in land use development will have an impact on the transportation requirements.

So, through such a series of successive approximations (or what is often called "feed back analysis"), a realistic, practical, and balanced plan may be devised, a plan that takes into consideration the major forces influencing urban growth and, at the same time, conforms to over-all community objectives and goals.[1]

Mathematical models, because they are inherently weak in dealing with small areas, are used most effectively when needs are studied on a broad scale. They are especially suited for metropolitan planning. When comprehensively researched, these models will doubtless be used increasingly for small areas.

For instance, the Philadelphia land use model described by Row and Jurkat was devised to forecast employment space requirements for different areas of the city, and several traffic models have also been designed to delineate traffic problems in various neighborhoods.

It appears that the most effective results will be obtained when a simple model is developed that can be applied on a regional basis, yet be adaptable to evaluate small area problems. At present, traffic models are closer to this goal.

Advantages of Models

The use of models in the city planning field will help to:

1. Understand factors that influence land development and traffic patterns.
2. Provide a better factual basis for plans.
3. Evaluate and test alternative plans.
4. Develop more realistic plans.

A mathematical model provides a systematic statement of relationships, and hence improves our conceptions of the forces associated with community growth and related urban transportation requirements. Since models can assist the planner in obtaining a clearer understanding of a community's problems and opportunities, models are helpful, too, in outlining the most appropriate land use and transportation plan.

For example, in the Washington, D.C., Mass Transit Study, conducted by the National Capital Regional Planning Commission, traffic model studies revealed that current growth patterns would result in a gigantic highway problem in a sector north of the central business district. The Commission had two alternatives: to encourage new employment centers to locate in outlying areas, thereby reducing downtown travel; or to depend on an extensive mass transit system including both local and express services to foster the development of the downtown area.

In many city planning decisions it is necessary to evaluate advantages and disadvantages of various alternatives. This point was affirmed during the Washington Transit Study when members of the Regional Planning Commission realized that highway improvements had to be studied in conjunction with the transit plan. The Commission studied and evaluated one land use plan and four alternative transportation plans. Each was

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[1] The use of models is discussed further by Hamburg and Creighton and by Booth and Morris.

designed to meet the transportation needs of the 1980 land use plan. Each plan varied with the type of transit facilities and services to be provided as well as with the numerous highway improvements to be incorporated. With mathematical tools, it was possible to estimate expected patronage of various transit proposals in addition to highway volumes. When compared, the estimates provided a picture of the advantages of each of the four alternatives. With this type of data, Washington is now deciding on its transportation program (see forecasts for two of the alternatives in Table 1).

Developing Models

The mathematical relationships which must form the basis for these new techniques should be determined by observing land use or traffic patterns over a period of time. For example, a study surveying the distribution of population before and after construction of a circumferential highway could reveal the impact that highway access has on residential development. However, such a study would indicate the effect of accessibility only. Additional studies should be undertaken to determine the influence of other factors and their interrelationships.

In the *traffic model* field, most of the completed work is based on origin-and-destination studies conducted by various state highway departments with the cooperation of the U.S. Bureau of Public Roads. Since more than a hundred of these studies have been completed, it is possible to compare traffic patterns among cities. The model used in Baltimore is the result of such an empirical investigation.

Consistent mathematical relationships usually can be found if there is adequate factual information available. However, many different hypotheses may first have to be tested. A hypothesis can be tested rapidly and accurately through the use of high-speed computers now commonly accepted in other fields. Computers permit rapid mathematical determination of the most important variables and of the extent to which they interrelate. Computers are not necessarily more accurate than standard desk calculators, but they are considerably faster. (As one authority wryly advises: "Computers aren't brains, just rapid morons.") Computers, and their use, are discussed in this issue by Creighton, Carroll, and Finney.

Some city planners, finding that it suits their needs, have applied mathematical models by using desk calculators in lieu of high-speed electrical computers. Although this method is less expensive when the job is small, more complicated problems are best solved on high-speed computers.

To choose the best method, a consultation with a computing center is recommended (a center interested

TABLE 1

MODE OF TRAVEL EXPECTED WITH ALTERNATIVE TRANSPORTATION PLANS, WASHINGTON, D.C.

Destination and Mode	1955 Survey Findings	1980 plans	
		Without Express Transit	With Express Transit
To downtown in A.M. peak-hour—inbound by:			
Auto (including taxi passengers)	105,000	140,000	100,000
Local transit	55,000	50,000	15,000
Express transit	....	....	75,000
Total	160,000	190,000	190,000
To downtown in 24 hours—in and out by:			
Auto (including taxi passengers)	800,000	1,130,000	950,000
Local transit	390,000	370,000	90,000
Express transit	....	....	460,000
Total	1,190,000	1,500,000	1,500,000
Within total urban area in 24 hours—all trips by:			
Auto (including taxi passengers)	2,495,000	5,205,000	4,955,000
Local transit	640,000	865,000	355,000
Express transit	....	....	760,000
Total	3,125,000	6,070,000	6,070,000

Source: Mass Transportation Survey, National Capital Region.

in processing data, not in selling computers). Also, a local corporation employing computers, or perhaps a university faculty member, may help in the decision.

More Research Needed

Most work in the *land use model* field has been done within the last two years. Various professional groups have been experimenting with *traffic models* for approximately five years; in the past two years major advances have been realized.

For a more proficient traffic model, researchers must become more knowledgeable concerning the precise impacts that fares, travel times, and comfort have on transit usage, as well as the factors affecting car ownership, and how traffic is distributed over a network of streets.

With regard to the land use model, the research needs are even more critical. Most contributing authors to this issue of the JOURNAL will doubtlessly agree that a really effective model is not presently available. More information about community growth and about the relationships of accessibility and land value on land development or redevelopment is necessary before land use models approach final stages. Knowledge of the factors prompting a manufacturer to relocate or expand is inadequate, and the influence of aesthetic taste and social ties on community growth has never been measured systematically.

These are but a few of the obstacles delaying the development of effective land use models. One thing, however, is certain—that with intensive work the job can be done.

The benefits accruing to our communities when the models are refined will be tremendous; but in the meantime the challenge can be met only by experimental application of these techniques and by more basic research. A check of one of the land use or traffic models or a historical analysis of land use and traffic patterns in your community will help to speed up this process.

With the achievement of more effective mathematical models, certain phases of city planning will become more exacting, thereby improving the quality of land use and transportation plans.

Certainly, as city planners we have the responsibility of expediting these improvements.

HANS BLUMENFELD

Are Land Use Patterns Predictable?

To provide a background for the other articles in this issue the author summarizes some of the studies that have identified key variables affecting urban growth patterns. The most consistent factor related to land use distribution is sheer distance, and especially distance from the CBD. In Philadelphia and Toronto urban density patterns have followed almost identical patterns over the past half-century, giving support to the "crest of the wave" theory of urban growth. Both residential and employment densities exhibit a consistently regular pattern that follows concentric rings out from the CBD. The observations reveal strong regularities of metropolitan land use patterns and hence raise the intriguing question posed in the title of this article.

THE RELATIONSHIP between land use and traffic generation has been identified sufficiently well to permit us to estimate the origins and destinations of urban travel. Indices of land use, population, and employment help us to predict traffic patterns; however, to make this travel prediction the planner must assume certain future spatial patterns of land use distribution.

Such a land use forecast is based presently on a "plan" evolved largely from judgment, and thus traffic analysts, who utilize scientifically based methods, must derive their results from a nonscientific basis. It is natural therefore to seek a scientific procedure for land use forecasting.

One way to forecast future events is by extrapolation of past trends. Such extrapolation is possible if two conditions are fulfilled.

First: The number of independent variables must be small. That is, it must be possible to eliminate most of the endless number of variables which actually influence events, either because their influence can be shown to be negligible or because it can be shown that they are so closely correlated with the selected independent variables that the latter can be substituted for them.

Second: The observations must cover a sufficiently wide and varied universe over a sufficient period to enable one to predict, with an acceptable degree of probability, the limits within which the observed correlations are valid.

On the implicit assumption that both conditions can be met, a number of independent variables have been used in an attempt to construct models of land use and population distribution.

Spatial Relationships

The horizontal dimensions of space on the earth's surface are certainly a basic determinant of population distribution. Investigating the settlement pattern in South Germany, Walter Christaller uncovered a definite pattern, a hierarchy of "central places."[1] The smallest central places served an area with a radius of about 2½ miles. A cluster of smallest central units was again served by a larger center, and so the pattern continued. Since circles do not dovetail, they may be modified into hexagonal areas. The result is a system of small-scale honeycombs within larger honeycombs. If horizontal space were the only factor, such a pattern of land use would develop. However, as Christaller recognized, this pattern is modified by political, topographic, and transportation factors.

Donald Bogue, analyzing the more recent settlement pattern of the United States, assumes 67 major metropolitan centers as "given" and investigates their influence on their sphere of dominance, measuring concentric zones of varying distance from the center.[2] He also

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[1] Walter Christaller, *Die Zentralen Orte in Suddeutschland* (Jena: Gustav Fischer, 1933).

[2] Donald J. Bogue, *The Structure of the Metropolitan Community* (Ann Arbor: University of Michigan, 1949); also, Hans Blumenfeld, "The Dominance of the Metropolis" (Comment), *Land Economics,* May 1950.

measures the influences of subcenters and major transportation arteries on individual sectors. Dependent variables are density of urban, rural nonfarm, and farm populations, and employment in manufacturing, wholesale trade, retail trade, and services. Sectional differences in over-all population density and economic development and other geographic factors are deliberately ignored. A fairly consistent pattern emerges.

Christaller, a geographer, and Bogue, a demographer, concentrated their studies on quantitative factors. Park and Burgess, sociologists, investigated differences in the social and economic characteristics of the population by concentric zones. They found that social-economic status increased with distance from the center. These findings were confirmed, for instance, by an analysis of the 1940 census data for the city of Philadelphia.[3] While population density (whether measured over-all, gross, or as net) decreased for all zones from the center to the periphery, dwelling-unit value and percentage of home ownership increased regularly to the zone of most rapid growth, which in the preceding decade had occurred between 7 and 8 miles from the center. Beyond this zone, residential value and home ownership decreased again.

The Park-Burgess pattern, valid for North American cities of the twentieth century, is a reversal of the older pattern developed in European cities during the preceding centuries. Thus, any theory can be valid only within the limits of a given social-economic structure and may change in scale or direction with future change of this structure.

Concepts based on differences related to the distance from center necessarily obscure the differences between sectors in each zone. Homer Hoyt found that certain sectors in United States cities show common characteristics through several concentric zones. Here, the determining factors appear to be: (a) rail and water transportation lines that attract industry; (b) predominant wind directions which attract high-income groups to the windward side, with lower-income groups residing on the leeward side. Again, these factors may be changed by historical developments, such as changes in means of transportation or in the class structure of society.

Both the concentric-circle and sector theories deal only with the two horizontal dimensions of space. Small heed has been paid the third, vertical, dimension. However, an investigation of the 1940 census data for the Philadelphia Metropolitan District indicated a consistent correlation between altitude and average (contract or estimated) rental value of dwelling units. Each additional dime of monthly rent corresponded to a foot in elevation above sea level.[4]

Much earlier, in 1927, the North Jersey Transit Commission had reported that a close direct or positive correlation existed between ground-level elevation and land values.

Surprisingly, my investigation of Manhattan between 59th and 110th streets, showed a similar correlation between rents and ground-level elevation, though the height of the buildings frequently exceeded the maximum difference in ground-level elevation. Each north-south row of blocks between Riverside Drive and Park Avenue was investigated, using the rental data of the 1940 and 1950 census. Figure 1 presents the 1950 data for the row of blocks immediately west of Central Park. In addition to altitude, high rents were evidently related to two more variables: nearness to subway stations and proximity to the city's core. The latter is a significant exception to the Park-Burgess pattern.

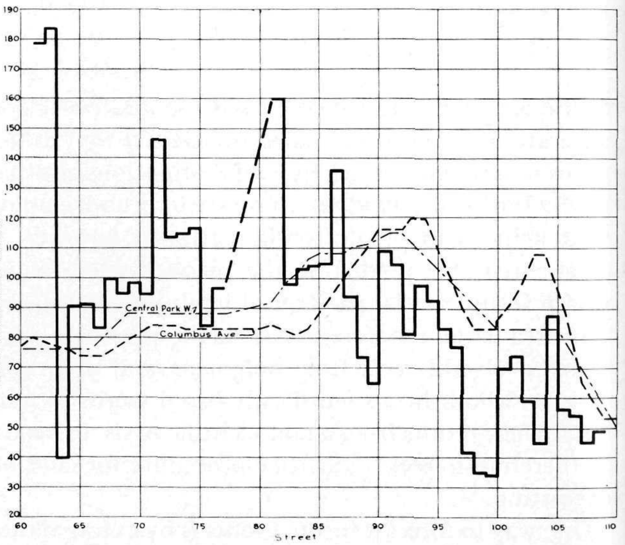

FIG. 1.—CORRELATION OF RENT AND ALTITUDE, NEW YORK, 1950 (*Note:* The western boundary of the blocks is Broadway from 60th to 66th streets, Columbus Avenue from 66th to 100th, Manhattan Avenue from 100th to 110th.)

Value of dwelling units may be an important factor in estimating traffic volumes. High values are correlated with high car ownership and high generation of vehicular trips. Too, high values are generally correlated with lower densities; although the Manhattan Westside study found a significant exception.

Correlation between altitude and value of dwellings can be observed in numerous United States and foreign cities. But most often the pattern appears to be of recent origin. In Paris, for instance, the influence of a reverse older pattern is still noticeable, with the aristocratic Faubourgs St. Germain and St. Honoré located in the valley and the working-class slums of Belleville and Menilmontant on the heights.

Trends of Population Distribution

The theories we have discussed thus far afford a valuable insight into the correlations important for constructing any model of future distribution of land use and population. These theories, however, do not yield quantitative forecasts, because they reflect correlations at a specific time and do not account for trends through time.

An attempt has been made to quantify the secular trend of distribution of population and over-all densities. Data from the decennial census counts of the period 1900 to 1950 for the Philadelphia metropolitan area have been assembled and analyzed for concentric zones up to 25 miles from the Philadelphia City Hall.[5] The main results are summarized as follows:

1. The spread of the metropolitan population from the center to the periphery has progressed with great regularity, with density decreasing consistently from the center to the periphery (with the exception of the core within 1 mile of City Hall).

2. With densities *decreasing* in the inner and *increasing* in the outer zones, the density differential between center and periphery decreases through time (the curve flattens).

3. The change of density in each zone appears to conform to a logistic curve, with zones from the center outward entering the curve successively, and each zone curve flattening out at a lower level than the next less distant one.

4. The rate of growth in any given period increases rather sharply for each succeeding zone, then gradually decreases and levels off. The zone of most rapid growth may be regarded as the crest of the wave of urban expansion.

5. This crest moves outward at a fairly regular rate (one mile per decade in the Philadelphia area).

The same method was utilized to measure the corresponding trend in the Toronto metropolitan area. The data were less reliable though and were available only for 1929, 1939, 1949, 1954, and 1955. Data for the area beyond the 8-mile circle, extending up to 18 miles, were available as a residual only. Nevertheless, the Toronto trend was remarkably similar to the trend in Philadelphia.

Dr. D. A. S. Fraser of K. C. S. Data Control Ltd., Toronto, was engaged to express these trends in a mathematical formula. It was found that the formula had to be limited to zones of suburban growth, from 4 to 18 miles in Philadelphia and from 3 to 8 miles in Toronto. Both the older core area, already fully developed at the beginning of the periods of investigation, and the outer, semirural, areas were omitted because of different trends. Several formulas were devised; the simplest is verbally expressed as follows: A concentric zone of a given density moves outward at a rate equal to 0.85 of the percentage growth of the total area population during the given period, multiplied by the mileage distance of the initial density zone from the center. For example: if total population during a specific period grows by 10 per cent, and if at the beginning of the period, densities x and y were found at 5 and 10 miles, respectively, from the center, then at the end of the period density x will be found at 5.425 miles and density y at 10.85 miles from the center. If total population grows by 20 per cent, density x will be found at 5.85 miles and density y at 11.70 miles from the center.

The constant 0.85 was found for Toronto; the corresponding constant for Philadelphia was found to be 0.83. The amazingly close relation of the two figures is probably coincidental. However, it is not improbable that the constants for most North American metropolitan areas vary within only a narrow range. It might be beneficial to test this hypothesis by similar investigations in other areas.

An attempt was made to use the 0.85 formula to forecast 1980 population densities for concentric zones between 3 and 8 miles from the center of Toronto. Resulting population figures for these five concentric zones yielded an excessive total and provided too little of the assumed total area population for zones under 3 and over 8 miles from the center. Note that the area total is built into the formula only as an independent variable, not as an automatic limit upon the sum of the zone results. Consequently, these results were adjusted downward proportionally to fit the total. The adjusted zone results served as controls for the population figures of each zone. The latter figures had been derived previously by the traditional method of estimating carrying capacity of each segment of each zone on the basis of natural conditions, historical trends, and existing zoning regulations. Application of the controls resulted in some adjustments.

It is evident that practical application of the results of the analysis of population trends by concentric zones is currently limited. Some reasons for this limitation are obvious:

1. The formula is based on the trend as observed during the first half and second quarter of the century, respectively. The trend may change.

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[3] Hans Blumenfeld, "On the Concentric-Circle Theory of Urban Growth," *Land Economics,* May 1949.

[4] Hans Blumenfeld, "Correlation Between Value of Dwelling Units and Altitude," *Land Economics,* November 1948.

[5] Hans Blumenfeld, "The Tidal Wave of Metropolitan Expansion," *Journal of the American Institute of Planners,* Volume XX, No. 1.

2. The formula is applicable only to the belt of suburban growth, and results must be adjusted to independent population estimates for the inner, urban, and the outer, semirural, zones.

3. Conclusions are valid only for each concentric ring as a whole, but yield no information on population densities (which may vary greatly) within the individual segments of each zone.

Densities are influenced by natural and political boundaries, as evidenced by the Philadelphia area study.[6] In addition, the existence of secondary centers affects the density within individual segments, though, unexpectedly, this does not affect the density of entire concentric zones.

The concentric-circle theory may be regarded as a special case of correlation of population distribution with centers of employment; the case, that is, where there is only one such center. It should be possible to find the correlation of population distribution with several centers of employment. This requires a reversion of the gravitation formulas now used to determine the distribution of a given purchasing power among several shopping centers at given distances between the shopping centers and the several units of purchasing power.

At first glance, such an exercise may appear to be of only purely theoretical value. Location of employment, even more than location of population, is dependent on individual decisions and therefore may be considered to be even less predictable. However, the location choice of industrial and commercial employment is more strictly limited by transportation facilities and other relatively permanent factors than is the choice of residence. Therefore, it can be predicted with greater confidence.

In the Toronto area, an attempt to correlate population distribution with a limited number of major employment centers is under way. The results thus far, although promising, are only fragmentary. If a satisfactory formula to express the presently existing correlation can be conceived, it may serve as a basis for calculating future population distribution on the basis of the assumed future distribution of employment centers.

Distribution of Nonresidential Land Uses

Few attempts have been made to construct models of nonresidential land uses. Adequate data have not been available for the construction of time series and the derivation of trends. However, some valuable material is available for the indispensible first step.

Figure 2 illustrates the density of population in 1956 at place of residence and at place of employment in Metropolitan Toronto. The zone within one mile of City Hall is primarily an area of employment. In the other zones the slopes for the employed population closely parallel those for the resident population. It appears that distribution of employment is correlated as consistently with distance from the center as is distribution of residence.

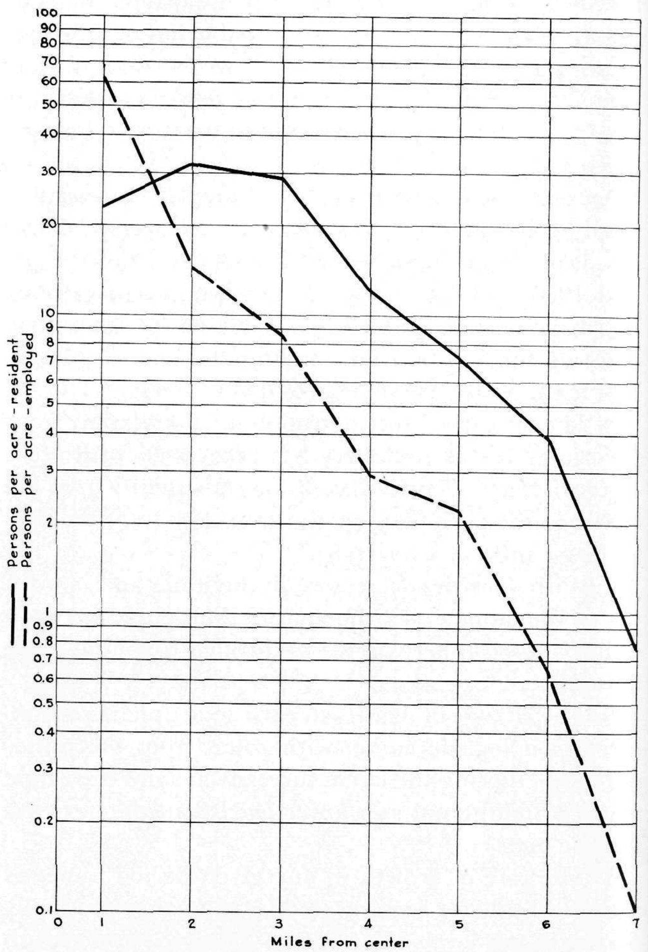

FIG. 2.—DENSITY OF POPULATION AND OF EMPLOYMENT BY CONCENTRIC CIRCLES, TORONTO, 1956

By calculating employment patterns, it is possible to arrive at approximate estimates of future trip distribution by concentric zones. Such estimates may be used as a control for the sums of trip predictions based on other methods for individual segments of each zone.

However, since space requirements for employment activities differ widely, a gross estimate of total employment cannot serve as a basis for a prediction of the land required for employment areas. The most pertinent and extensive of land requirements are those for the manufacturing industries, which must be investigated separately.

Figure 3 depicts the relative density of residential population and manufacturing employment in 1940 and 1943, respectively, for 5 concentric zones in the city of Philadelphia. The decrease in manufacturing employment density, although rather consistent, is less drastic and not so regular as the decline in population density by distance.

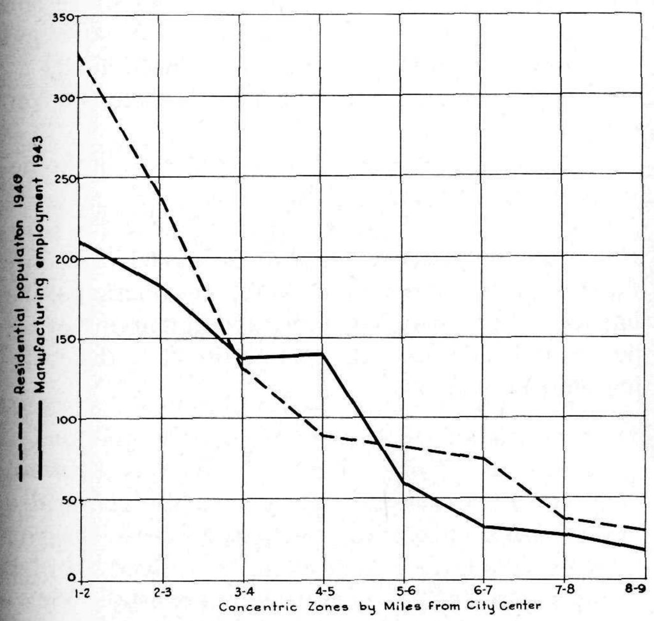

FIG. 3.—DENSITY OF POPULATION AND OF MANUFACTURING EMPLOYMENT, PHILADELPHIA 1940–1943

These densities express only the relation of persons employed in manufacturing to the total area of the zone. To derive the area in manufacturing use, the area required by each manufacturing worker must be known.

In the industrial districts of the Philadelphia metropolitan region in 1944 the number of persons employed per gross industrial acre averaged 51.4 within 2 miles of City Hall, 23.8 between 2 and 5 miles, and 15.7 over 5 miles.[7] Thus the decrease in density from the center to the periphery, or the increase in land used per capita, holds for both residence and employment space. This finding in the Philadelphia study is remarkable because the area between 2 and 5 miles contains extensive tank farms and railroad yards, and the outer area contains about a dozen fully matured industrial towns.

The percentage of the total area of any zone used for manufacturing is related to the number of industrial workers per square mile of total area. It is also related to the amount of industrial land used per worker. As we have shown, the number of workers per square mile decreases and the land used per worker increases with distance from the center. However, these two trends do not cancel each other out. A study of land use in the Philadelphia Metropolitan District in 1944,[8] showed that within 5 miles of City Hall industrial land use accounted for 19.3 per cent of the total area, between 5 and 10 miles for 2.3 per cent, and beyond 10 miles for 1.2 per cent.

Institutional land use is considered to be the third most important land use category. The Philadelphia study also provided information on the gross land area used for educational, health, welfare, and penal institutions, and for cemeteries. Only areas of about 15 acres or more were listed as "gross land area" of specified use. Smaller land parcels, such as neighborhood schools and playgrounds, were included in the "gross area" of the predominant surrounding land use. The following table presents the correlation of institutional land use, as defined above, with population and gross residential area in three concentric zones.

TABLE 1

INSTITUTIONAL ACRES,
PHILADELPHIA METROPOLITAN AREA, 1944

Miles from center	Per 1,000 population (1940)	Per 100 acres of gross residential area
0–5	1.22	9.3
5–10	4.39	9.3
Over 10	27.10	35.8

In the zone beyond 10 miles, several large institutions were operating farms as well as performing their standard functions, and farming could not be separated from the areas of the institutions. Therefore, such areas are not comparable with those in the two inner zones. Within the limits of this study, comparison between these two zones reveals that these land uses have a constant relation to residential land, but not to population. In the 5–10-mile zone, about 3½ times as much institutional land is used to serve a similar number of people as in the 0–5-mile zone.

This is surprising, because a person's need for institutional services is not dependent on the location of his residence. Many services are supplied by various levels of government; and official governmental standards require that certain areas be allocated in relation to the number of persons served, for example, a specified school acreage for a certain number of students. However, in Philadelphia, the net acreage of public schools in 1944 for each 1000 students was: within a 1-mile circle, 0.78; within 1–5-mile circles, 1.52; within 5–10-mile circles, 3.15.

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[6] *Ibid.*, Tables 7 and 8.

[7] Derived from *Industrial Land Use Plan*, Table VIII and Map 3 (Philadelphia City Planning Commission, 1950).

[8] *Land Use in Philadelphia Metropolitan District 1944* (Philadelphia City Planning Commission, 1949).

Institutional densities, like residential and industrial densities, follow the pattern of regular decline from the center toward the periphery. This is true because as demand for land and prices of land decrease or increase, *all* land uses expand or contract with the price. Therefore the trend of population distribution by concentric circles can serve as a guide in forecasting the distribution of all land uses.

Possible Development of Land Use Models

The findings discussed here can serve only as very broad guides. The use of each segment of land is dependent on a great many variables: topography (altitude and slope), soil, climate, relation to transportation facilities and to centers of employment and of service, existing development and occupancy, zoning, etc. As stated above, the first condition for constructing a model is to reduce the number of these variables.

Apparently, the net result of these variables is expressed rather accurately by a curve representing the population density over time. In addition to past densities, distance from the center and time periods are used as variables in this method. This reduction to a sum of three variables fulfills the first condition. As the family of density curves is based on observations in several metropolitan areas over several decades, the second condition—validity within the limits of the area and period of prediction—also appears to be fulfilled.

This discussion of land use models leads to two conclusions:

First: With more research it may be possible to develop useful land use models.

Second: No matter what degree of success city planners attain in constructing models, models can only supplement, not supplant, the careful evaluation of the impact of the changing needs and intentions of all people and agencies in the community upon the evolving land use pattern.

JOHN R. HAMBURG and ROGER L. CREIGHTON

Predicting Chicago's Land Use Pattern

The planning of community facilities requires accurate quantitative estimates of the area, type, intensity, and location of land uses required by the growth of urban activities. The distribution of these activities and the intensity of their use of land are highly related to accessibility as measured by distance from the CBD. This paper outlines a procedure whereby area-wide estimates of future population and economic activity can be distributed to small subareas so that measures of local land requirements may be obtained.

PROBLEM SOLVING is often less difficult than the formulation of adequate problem statements. Once a problem is correctly identified, the solution is readily forthcoming and may even be suggested by the problem statement itself. Land use forecasting, a relatively unused tool, holds much promise as a technique to identify and measure certain urban problems which must be solved by city planning.

Some of the advantages of land use forecasting can be illustrated by the following example. The population forecast can be divided into age components and used to scale the total demands for educational facilities in a city. If this forecast is further subdivided into age forecasts by small areas, then each school district's needs for classrooms have been identified. With the resulting estimates, and within the ranges of accuracy of such forecasts, a program of school construction in each district can be prepared with full awareness of the over-all demands for educational facilities. Thus, when the problems of the future have been clearly defined, the planning and administrative solutions follow in order.

What are the problems to be identified and measured by a land use forecast? The more obvious are listed as follows:

a) The transportation requirements resulting from growth and change in urban land use
b) The utilities requirements
c) The requirements for governmental services, such as schools
d) The total and proportionate amounts and the locations of land which must be set aside, either by zoning or through acquisition, for various activities
e) The location of the areas of most rapid urban growth, where adequate planning and land use controls need to be applied.

With these problems of the future identified in quantitative terms, the planner can program both community and professional resources to solve the problems created by urban growth. Whatever his tools, whether zoning, subdivision regulations, public acquisitions, reservations of rights-of-way, or the capital budget, he will know when and where they must be applied.

The Land Use Forecast as an Aid to Transportation Planning

The Chicago Area Transportation Study (CATS) was given the responsibility for preparing a transportation plan for the Chicago area. To do this, the traffic problems of 1980 had to be estimated, for plans designed to solve the traffic problems of 1956 would obviously be inadequate for any rapidly growing area.

Some means, therefore, had to be developed for taking the 1956 travel survey data and projecting it into the future accurately, in measured terms, and for precise geographic locations. This could be done by relating travel to land use, since it is the activities of people on land which generate travel. The relationships between 1956 land use and 1956 travel provided the trip generation rates which (with necessary adjustments) could be applied against a land use forecast to give the

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future estimates of traffic generation. In turn, future traffic generation, by a series of elaborate calculations, can be used to estimate the flows of travel on streets and mass transportation systems throughout any part of an urban area.

Predicting land use therefore became an integral part of the Study's processes for preparing a transportation plan. As a starting point an extremely large and very detailed inventory of land use was obtained. The techniques of this inventory, which included both land area and floor area surveys, are described briefly in the article on data processing in this issue of the JOURNAL. It is an absolute requirement for land use forecasting as well as for the study of trip generation that detailed, measured data be available from such a land use survey. These data must be organized in such form that they can be arrayed in a variety of ways for analysis.

Procedures for land use forecasting had to meet certain requirements. First, the forecasting procedure had to be objective and systematic so that two persons using the same rules would achieve the same results. Second, the procedure had to be sufficiently mechanical so that it would be susceptible to machine processing. The Study's planning area had been divided into nearly 600 analysis zones and the use of mechanical means to forecast the land use in each zone was a necessary labor-saving device. Finally, judgment was obviously inadequate as a basis for making the multiple decisions required in such a forecast. Quantified regularities in the organization of land use within an urban area had to be found and applied in order that these decisions might be made. The land use data obtained by survey showed that these regularities do exist.

The regular organization of land use within an urban area was employed in the forecasting procedure not as a blind extrapolation of existing findings, but accompanied by a systematic organization of ideas regarding the structure and growth of the city. Such an organized view of the statics and dynamics of an urban area gave perspective to the forecast, and this perspective was one of the devices working to insure the reasonableness of the forecast itself. Other devices used to insure a reasonably accurate forecast were (a) the control provided by having sound estimates of total growth and (b) the control resulting from the constraints to growth imposed by the available land in the areal units for which forecasts were made.

In simplest terms, urban structure and growth were viewed in the following way.

If the various activities of the community are thought of as competitors for the available sites, the most desirable sites should receive the highest bid. And the higher the cost of the site, the more intensively the successful bidder must use his site, which generally results in multistory structures.

The most desirable sites, typically, are those which are most accessible to other sites. In a hypothetical city with flat terrain, the central point is the most accessible to all others. But accessibility is defined by a transportation network. It is a complicated measure, since there may be several speeds and several modes of travel. Generally, the central business district is the most accessible location in an urban area. It claims the greatest densities and those activities (typically commercial) to which accessibility is most important.

Peripheral sites have less accessibility. Therefore they are acquired for those uses which do not require a high degree of accessibility. Residential and related activities are developed on these less accessible lands. Some accessibility is required, however, to jobs, shopping, and other urban services; therefore residential activities tend to cling to the mass of the existing city where services exist.

For a given time period, there is a balancing of costs resulting in a given urban structure. The center attracts those activities which require and can pay for accessibility and which can function at certain degrees of density. Other activities arrange themselves in accordance with their requirements for accessibility and space and their ability to pay for both. These forces result in gradual and regular declines in densities as distance from the central business district increases. They also result in an orderly array of land uses around the central business district.

Over periods of time, accessibility may change, generally through improvement in transportation technology. Faster transportation and more flexible transportation, makes more urban land accessible. This then operates to permit low density of development.

Developed sites, however, resist changes in accessibility and change only very slowly. Sometimes they may even force new means of transportation to serve them, even at high cost, in order to maintain this accessibility—and, hence, value. Thus, there is a great stability in the existing urban pattern.

Forecasting the Future Land Use

The forecasting of future land use in the Chicago Study was treated largely as a distributional problem in which aggregate population and worker forecasts were distributed to small areas.

The procedure used to estimate future land use by analysis zone required the following steps.

1. *Setting Future Population and Worker Densities*

Analysis of population density patterns indicated that there was a systematic decline in net residential density as distance of place of residence from the CBD increased (see Figure 1). This pattern was regular enough to suggest the use of norms based on location with respect to the CBD. In order to decide which zones would be set at the norms and which zones would continue at their current density, the 582 CATS analysis zones were grouped according to the percentage of currently used land to total usable land. This procedure resulted in three basic groupings:

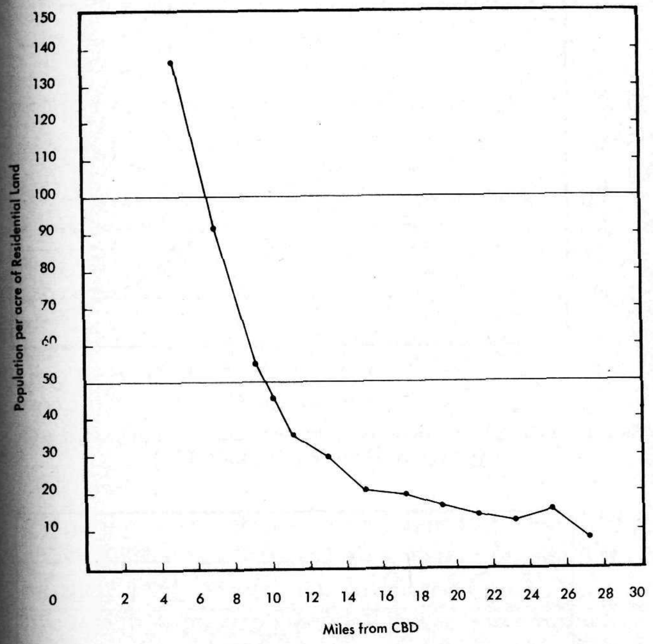

FIG. 1.—POPULATION DENSITIES BY DISTANCE FROM THE CBD, CHICAGO AREA, 1956. (Institutional population is not included.)

a) *Zones over 75 per cent developed in 1956.*—It was assumed that these zones would continue at the same residential density as in 1956. The majority of these highly developed zones (256) were in the city of Chicago.

b) *Zones between 75 per cent and 50 per cent developed.*—A normative density was estimated by using the appropriate sector regression curve of density on distance. This estimated density was compared to the current density; and if there was less than a 10 per cent difference, the existing density was continued. Careful inspection of the aerial photography and existing development were the basic references for setting the future densities for the remaining zones.

c) *Zones less than 10 per cent developed.*—The sector distance norms were used to estimate the future densities. Most of these zones had densities which varied between 8,000 and 10,000 persons to the square mile of residential land.

The estimation of the future worker densities by zone was less precise than the estimation of the resident population densities. The regular declines observed in 1956 (see Figure 2) served as the base for the estimation of future worker densities.

The bulk of all future industrial expansion is expected to fall beyond a radius of 9 miles from the CBD. Worker densities for zones between 9 miles and 12 miles were set at 29 workers per net acre of manufacturing land. For zones between 12 and 18 miles, densities were set at 20 workers to the acre; and for zones beyond 18 miles, the density assumed was 17.5 workers to the acre.

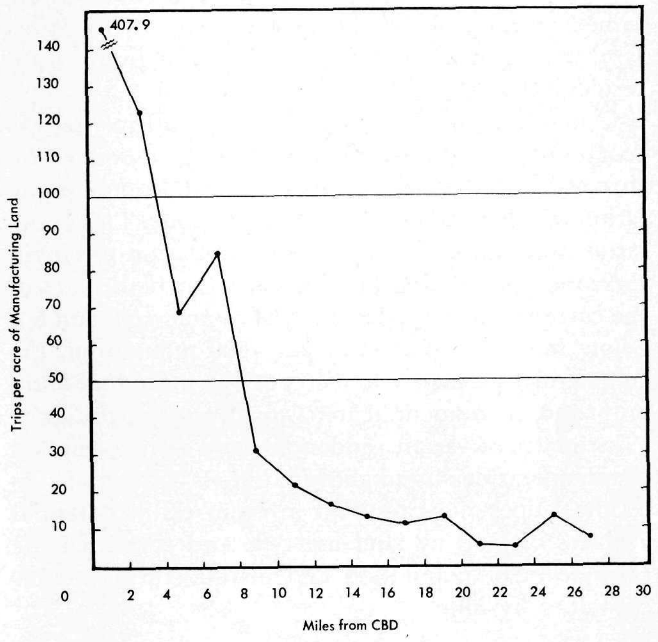

FIG. 2.—MANUFACTURING WORKER DENSITIES BY DISTANCE FROM THE CBD, CHICAGO AREA, 1956. (Densities are expressed in terms of first work trips, which are roughly 85 per cent of total employment.)

2. *Designation of Land Use*

With future densities estimated, the question of the rate of utilization of land for population and workers was resolved. Next, the problem of how much land was available for different activities by zone had to be answered. It was assumed that currently developed land would continue in that use until the target year 1980, except for planned redevelopment projects, the central business district, and committed demolitions for highway construction. Zoning regulations were used to designate vacant land as residential, industrial, or commercial.

Additions to the major park system were estimated after contacting the Forest Preserve officials and reviewing the current ratios of open space and population in the study area. This land was subtracted from vacant, zoned, residential land by zone.

Records of industrial land on the market but not currently zoned as industrial are maintained by the Commonwealth Edison Company. These sites were identified, reviewed, and the areas of some were added to vacant industrial land and subtracted from vacant, residentially zoned land.

Street area was considered constant for zones with less than 10 per cent of their total areas vacant in 1956. For zones having a large amount of vacant unplatted land, streets were added at a variable rate according to the distance from the CBD.

Potential increase in public building land was obtained by multiplying the vacant, residentially zoned land by .06, which amount was deducted from vacant residential land.

Commercial land was obtained by multiplying the remaining vacant residential land by the estimated future residential density to obtain the additional population which could be absorbed by the zone. This population was added to the current population to obtain the zone's population holding capacity. If the sum of the current commercial and zoned commercial land fell below the ratio of 2 acres per 1000 population, the commercial acreage was increased to meet this minimum and the residential area was adjusted accordingly.

Estimates of vacant residential land were a residual of the operations listed above.

These operations resulted in estimates of potential acreages of land by land use type and permitted the calculation of population and manufacturing-worker capacities by zone.

3. *CATS Area Population Capacity*

"Population holding capacity" by zone was obtained by multiplying the acreages of designated residential land by the estimated residential density for each zone and adding this to current population. On the basis of these calculations, if all the vacant land in the CATS study area were developed, the area could accommodate about 9,200,000 persons. The 1956 population was 5,200,000 or 57 per cent of the capacity.

Figure 3 illustrates the distribution of the proportion of existing population to population capacity by two-mile rings from the CBD. The per cent of population capacity declines sharply from 9 miles to 19 miles and then less rapidly to 10 per cent at 29 miles distance from the CBD.

Figure 4 shows the comparable gradient for manufacturing workers. Here again the sharp decline with a flattening at the edges of the study area is apparent.

Both these distributions illustrate the tremendous organizing impact of the central area on the distribution of population and workers and, hence, the development of land. While there are sectoral effects present, these are assumed to be the distortions of a purely concentric ring growth based on equal distances instead of equal time. If adequate measures of travel friction had been available at the time these sectors experienced heavy growth, sectoral variations might be largely explained.

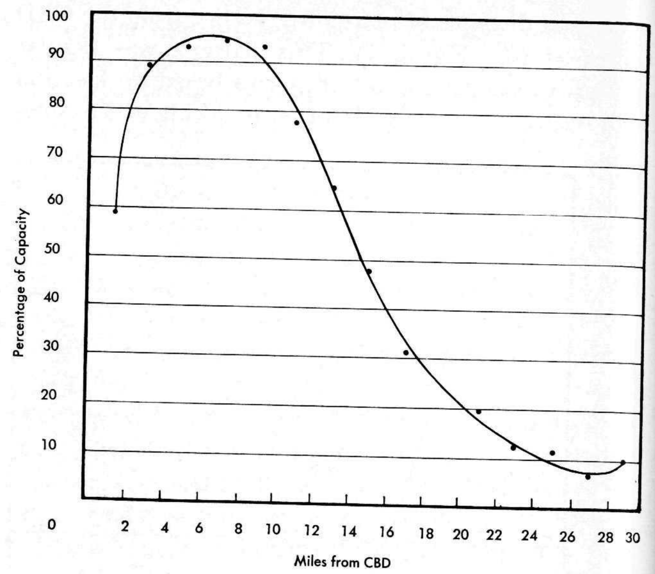

FIG. 3.—1956 POPULATION AS A PERCENTAGE OF POPULATION CAPACITY. (By distance from the CBD.)

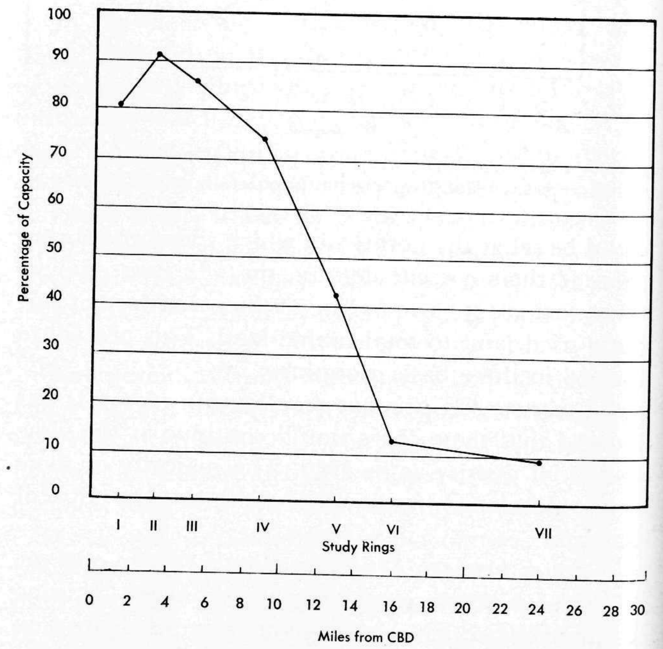

FIG. 4.—1956 MANUFACTURING WORKERS AS A PERCENTAGE OF MANUFACTURING CAPACITY. (By distance from the CBD.)

4. *Forecast of 1980 Population and Workers*

For the CATS study area, the 1980 population estimate was 7,752,000. This is an increase of about 48 per cent and well within the estimated population capacity of the area (see Table 1).

The 1980 estimated population amounted to 84 per cent of the estimated capacity, which left space for about 1.5 million persons or about 16 per cent of the area's holding capacity.

The forecast of manufacturing workers was obtained from an economic analysis using an "input-output" technique. The 1980 forecast of manufacturing workers was 1,098,000 as compared to 857,000 in 1956. This is an increase of 28 per cent compared to a 48 per cent increase in population (over-all increase in employment was 52 per cent). The lower rate for manufacturing results from a relatively greater increase in productivity.[1] The relation to capacity is shown in Table 1 which indicates that on an aggregate basis, there is ample manufacturing land in the study area.

TABLE 1

COMPARISON OF 1956, 1980, AND CAPACITY POPULATION

Year	Population		Mfg. Workers	
	Number	Per cent of capacity	Number	Per cent of capacity
1956	5,201,000	57	857,000	55
1980	7,752,000	84	1,098,000	70
Capacity	9,188,000	100	1,560,000	100

5. *Population Distribution*

The spatial distribution of 1956 per cent population capacity displayed a distinct pattern of gradual build-up to a peak of 96 per cent at 7 miles with a sharp decline to 19 miles and then a gradual decline to the edge of the study area (see Figure 3). Analysis of trends for the city of Chicago, based on census tract data, revealed much the same pattern. Successive time cuts have shown that the ring with the highest per cent population capacity is moving slowly outward and the inner rings, which were previous highs, are declining.

The procedure for estimating the 1980 distribution of per cent of population capacity by distance ring from the CBD centered on estimating (1) the 1980 peak, (2) the amount of decline for the rings closer to the CBD, and (3) the slope of the curve from the peak to the edge of the study area. The curve resulting from these components must satisfy the aggregate population estimate for the target year.

The 1980 peak population capacity was set at 11 miles from the CBD, which represents a rate of movement of 1.6 miles per decade. This was the approximate rate of movement from 1920 to 1956.

Very slight decreases were forecast for rings within 10 miles with the exception of the 0–2-mile ring.[2]

For distance rings beyond the 10–12-mile ring, a semi-logarithmic relation between distance and per cent capacity was assumed and the slope was adjusted so that the over-all shape of the curve of per cent population capacity for 1980 resulted in a total area population of 7,752,000 persons. The resulting distribution by distance is shown in Figure 5.

After this relationship between distance and the distribution of 1980 population was established, sector and then zonal estimates were made on the basis of the present capacity and the proximity of each zone to an expressway and/or to an incorporated area which could provide needed services. The results were then mapped and reviewed on the basis of reasonableness.

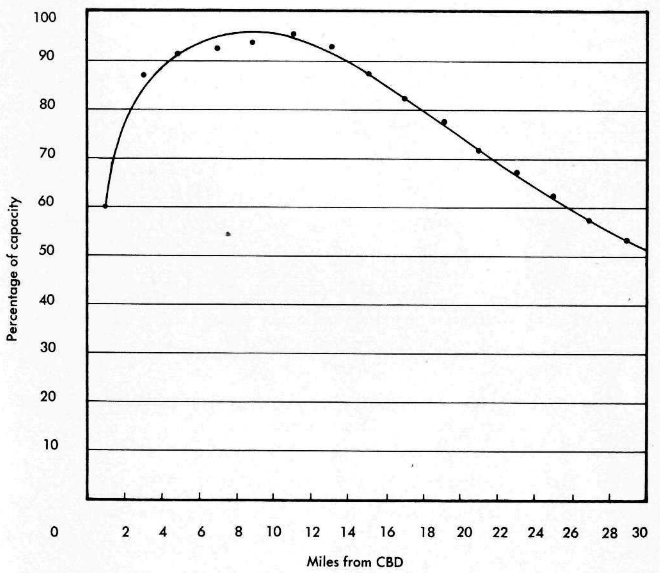

FIG. 5.—ESTIMATED PERCENTAGE OF POPULATION CAPACITY. (By distance from the CBD, 1980.)

Conclusion

Some planners may object that land use forecasting is too deterministic and that it usurps the planning function by eliminating decisions which should be made by design and planning judgment. Nothing could be further from the truth.

A population prediction does not prevent the school planner from exercising his functions. The behavior of materials on which engineering depends does not prevent the architect from designing; in fact, advances in engineering theory free the architect for bolder and more dramatic designs within the limitations of the materials. In the same way, the land use forecast, which acknowledges certain deterministic elements in urban growth, should free the planner for more productive effort.

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[1] Irving Hoch, "Forecasting Economic Activity For the Chicago Region," Highway Research Board, 1959.

[2] A comprehensive development plan for the central area of Chicago has been submitted to the city of Chicago by the city plan commission. This plan contemplates a significant increase in population in the central area. When the exact population of this proposal is fixed, this assumption of decline would necessarily be reviewed and revised accordingly.

Land use forecasting depends on more and better organized data and on additional knowledge about cities which such information will inevitably bring about. The land use forecast points out those basic forces, such as accessibility and population growth, which control urban development. The knowledge of what is determined permits a clearer vision of where effective decisions can be made. As a result, limited professional resources can be focused on those aspects of urban development which can be controlled.

There is a final and quite significant advantage of land use forecasting. Land use projections should provide a basis for integrating land use planning and transportation planning, resulting in a more nearly balanced relationship between urban growth and the construction of transportation facilities.

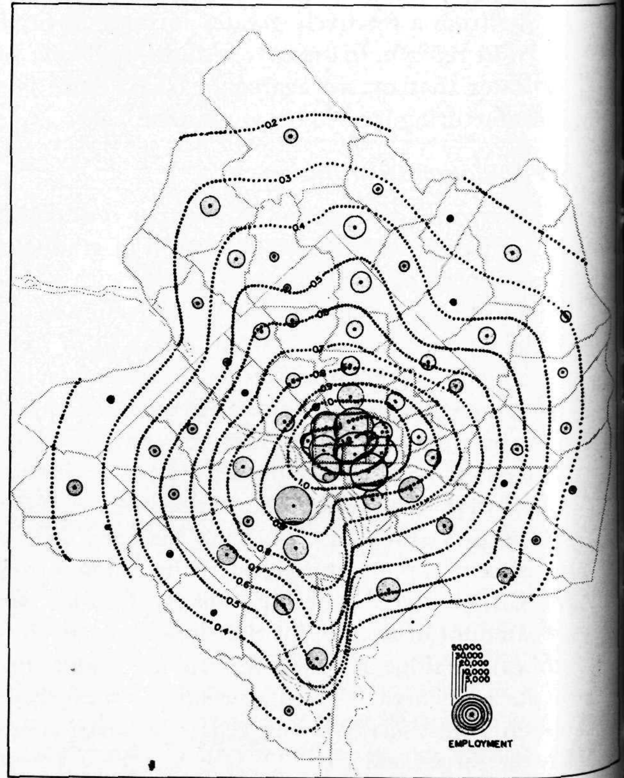

FIG. 1.—Accessibility to Employment, Washington, D.C. Metropolitan Area. Contour lines connect points of equal accessibility.

WALTER G. HANSEN

How Accessibility Shapes Land Use

An empirical examination of the residential development patterns illustrates that accessibility and the availability of vacant developable land can be used as the basis of a residential land use model. The author presents an operational definition and suggests a method for determining accessibility patterns within metropolitan areas. This is a process of distributing forecasted metropolitan population to small areas within the metropolitan region. Although the model presented is not yet sufficiently well refined for estimating purposes, the concept and the approach may be potentially useful tools for metropolitan planning purposes.

Author's note: This article is a preliminary presentation of certain concepts and findings developed while the author was attending the Massachusetts Institute of Technology under Public Law 85–507, which permits employees of the federal government to extend their education in areas closely allied to their work.

This study is part of a broader research project of the Bureau of Public Roads, designed to explore empirical relationships between land use and highway traffic with a view to coordinating and improving urban planning and highway planning.

City planners have continually emphasized the far-reaching effects that accessibility has on the development of land. The more accessible an area is to the various activities in a community, the greater its growth potential.

Consistent with this general concept of a relationship between accessibility and land development, a land use model, based on a realistic measurement of accessibility, can be developed. Such a model would relate the accessibility of an area to the rate and intensity of the land development in that area.

This paper explains the development of a residential land use model—a process of distributing total metropolitan population growth to small areas within the metropolitan region. Similar models, though more complex, are being investigated for commercial and industrial development.

Because a majority (80 per cent) of total personal travel is for work, shopping, and social purposes, this study has limited its investigations to the examination of the relationships between residential development and accessibility to commercial, industrial, and residential locations. These relationships coupled with the availability of space for development form the basis of the proposed residential land use model.

Measurement of Accessibility

As used in this paper, accessibility is defined as the *potential* of opportunities for interaction. This definition differs from the usual one in that it is a measure of the *intensity of the possibility of interaction* rather than just a measure of the ease of interaction. Defined in this manner, accessibility is a generalization of the population-over-distance relationship or "population potential" concept developed by Stewart.[1]

In general terms, accessibility is a measurement of the spatial distribution of activities about a point, adjusted for the ability and the desire of people or firms to overcome spatial separation. More specifically, the formulation states that the accessibility at point 1 to a particular type of activity at area 2 (say employment) is directly proportional to the size of the activity at area 2 (number of jobs) and inversely proportional to some function of the distance separating point 1 from area 2. The total accessibility to employment at point 1 is the summation of the accessibility to each of the indi-

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[1] J. Q. Stewart, "Demographic Gravitation: Evidence and Applications," *Sociometry* 11:1–2 (2/5/48), 31–58.

vidual areas around point 1. Therefore, as more and more jobs are located nearer to point 1, the accessibility to employment at point 1 will increase.[2]

Most of the controversy concerning gravity or potential models has surrounded the question of what the function of distance should be. It is generally agreed, and empirical examination indicates, that an exponential function should be used; that is, the measurement of distance separating the various areas should be raised to some power.

Unlike the contention of Stewart and others that this exponent should be unity, the assumption here is that the value of the exponent in this accessibility or potential model must be the same as that used in the gravity model. However, expirical tests of gravity models have resulted in exponent values that range from 0.5 to almost 3.0. When only those examinations conducted within urban areas are considered, the variation in the exponent for different trip purposes seems reasonable.[3] These studies indicate decreases in the exponent as trips become more important, i.e., school trips 2.0+, shopping trips 2.0, social trips 1.1, work trips 0.9. Inasmuch as distance appears in the denominator of the gravity model, a decrease in the exponent means that distance becomes a less restrictive factor. In short, the variation in the exponent shown above means that people are willing to travel farther to work than they are for any of the other purposes.[4]

It is when the results of these intraurban studies are compared to the findings of interurban examinations that an unexplainable variation in the value of the exponent appears. The analyses carried out in interurban travel reveal exponents of between 2.5 and 3.0.[5]

One reason for this apparent variation in the results of the intra- and inter-urban investigations is that these studies did not include terminal time or terminal effect in the measurement of distance. In interurban travel, since most of the trips are relatively long, the effect of omitting from 5 to 6 minutes of terminal time is probably negligible. In intraurban travel, however, where the median travel time is usually less than 20 minutes, a 5 to 6 minute terminal time would have considerable effect on total trip time.

To determine the effect of terminal time on the exponent of distance, the results of an analysis of travel patterns in Baltimore, Maryland, were examined.[6] The examination showed that, if driving times alone were used as a measure of distance, the exponent did not remain constant but increased as the time of separation increased. By incorporating from 5 to 6 minutes of terminal time into this measure of separation the variation in the exponent for any particular type of purpose of trip was greatly reduced.

When the separation of areas was expressed in terms of travel time plus terminal time the exponents for the various types of trips were found to be: work trips 2.20; social trips 2.35; shopping trips 3.00. These values are consistent with those determined by the various interurban examinations and were incorporated into the formula for computing accessibility.

Empirical Analysis

Data for the Washington, D.C., metropolitan area were used for empirical examinations of the relationships between residential development and accessibility.[7] Origin and destination studies, conducted in 1948 and repeated in 1955, supplied the bulk of the information necessary to calculate the accessibility measurements and to determine the pattern of residential, commercial, and industrial development over a period of seven years.

Table 1 illustrates the kinds of data used to calculate the various measurements of accessibility. Using the formulas developed in the preceding section, the accessibility to employment, population, and shopping opportunities were calculated for 70 areas in the Washington metropolitan area. Since accessibility is a spatially continuous measurement, it can be mapped in much the same way as heights are depicted on a topographic map.

TABLE 1

Data for Accessibility Calculations

Accessibility to	Units used to Express Activity Level or Size	Exponent of Distance*
Employment...............	Number of jobs	2.20
Shopping opportunities.....	Annual retail sales	3.00
Residential activity........	Population	2.35

* Distance is expressed in minutes of off-peak driving time plus 5 to 8 minutes of terminal time.

The map in Figure 1 on page 72 shows the lines of equal accessibility to employment for the Washington area in 1955. Similar maps may be conceived for accessibility to population and to shopping opportunities.

To determine the relationship between residential development and accessibility, it is first necessary to account for the zonal variation in land available for residential development. This was done by distributing total metropolitan growth to the individual zones on the basis of vacant developable land; i.e., if Zone A contained 10 per cent of the vacant land in the metropolitan area, 10 per cent of the expected growth was assigned to Zone A. This proportion of the total metropolitan development assigned to each zone is termed the *probable development.*

If there is a difference between the probable and actual development, it is assumed that the variance is related to accessibility. One way of expressing this difference is to divide the actual development by the probable development. This factor is termed the development ratio.

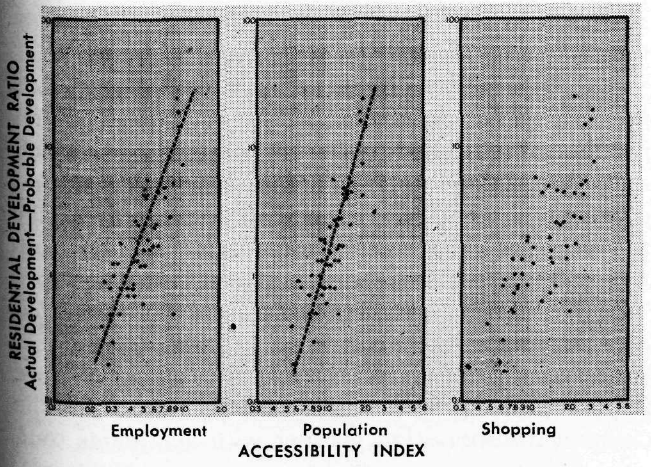

FIG. 2.—Accessibility and Residential Development

The residential development ratio was calculated for each of the areas displayed in Figure 1. Subsequently, these development ratios were examined to reveal whether they varied systematically with the various measures of accessibility. Observe the results in Figure 2. Visual examination suggests that the correlations between the development ratio and the measures of accessibility to employment and population are quite high.

The free-hand line in Figure 2, approximating the relationship between the development ratio and accessibility to employment can be expressed by the following formula:

$$D_1 = KA_1^{2.7}$$

where

D_1 is the development ratio for Zone 1;

A_1 is the accessibility to employment at Zone 1;

K is a constant of proportionality.

Using this relationship it becomes possible to estimate the residential growth in any zone if the accessibility to employment and the amount of developable land of the zone are known. As previously described, the probable development in any zone is determined on the basis of the proportion of the developable land in that zone. To estimate the actual development, the probable development is multiplied by the development ratio (D_1) (which in Washington is equal to 13.7 times the accessibility to employment raised to the 2.7 power).[8]

This method was used to estimate the residential growth from 1948 to 1955 for each of the zones in the Washington metropolitan area. A comparison of the estimated growths to the actual growths showed that 40 per cent of the zonal estimates were within 30 per cent of the actual growths and 70 per cent of the zonal estimates were within 60 per cent of the actual figures. When it is remembered that these estimates are based on only two independent variables, accessibility to employment and vacant land, the results are quite promising. The inclusion of the other measures of acces-

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[2] More formally this concept can be expressed by the following formula:

$${}_1A_2 = \frac{S_2}{T_{1-2}^{x}}$$

where

${}_1A_2$ is a relative measure of the accessibility at Zone 1 to an activity located within Zone 2;

S_2 equals the size of the activity in Zone 2; i.e., number of jobs, people, etc.;

T_{1-2} equals the travel time or distance between Zones 1 and 2;

x is an exponent describing the effect of the travel time between the zones.

If there are more than two zones involved, the formula becomes:

$$A_1 = \frac{S_2}{T_{1-2}^{x}} + \frac{S_3}{T_{1-3}^{x}} \cdots + \frac{S_n}{T_{1-n}^{x}}$$

This is the formula which was used to calculate the variation in the accessibility between areas.

[3] J. Douglas Carroll, Jr., and H. W. Bevis, "Predicting Local Travel in Urban Areas," *Papers and Proceedings of the Regional Science Association,* Vol. 3, 1957. See also Alan M. Voorhees, *A General Theory of Traffic Movement,* (the 1955 Past Presidents Award Paper, Institute of Traffic Engineers).

[4] These exponent values are tentative. Additional research is being done by the Bureau of Public Roads to develop and statistically evaluate these exponents for the Washington, D.C., area.

[5] J. Douglas Carroll, Jr., "Spatial Interaction and the Metropolitan Description," *Papers and Proceedings of the Regional Science Association,* Vol. 1, 1955.

[6] For an explanation of the mechanics of this type of analysis, see *Detroit Metropolitan Area Study,* July 1955, Vol. 1, pp. 92–93.

[7] The travel data used in the study were collected in 1948 and in 1955 in two origin-and-destination surveys conducted by the Regional Highway Planning Committee for the Washington Metropolitan Area, financed jointly by the highway departments of the District of Columbia, Maryland, Virginia, and by the Bureau of Public Roads. Land use and economic data were obtained from the National Capital Planning Commission and the National Capital Regional Planning Council.

[8] A more generalized estimating model is shown by the following formula:

$$\frac{P_1}{P_t} = \frac{D_1O_1}{D_1O_1 + D_2O_2 + \cdots D_nO_n}$$

substituting $KA^{2.7}$ for D, and cancelling the K:

$$= \frac{A_1^{2.7}O_1}{A_1^{2.7}O_1 + A_2^{2.7}O_2 + \cdots A_n^{2.7}O_n}$$

where

P_1 equals the increase in residential population in Zone 1;

P_t equals the total increase in residential population for; the entire metropolitan area

O_1 equals the developable land in Zone 1.

sibility through multiple correlation will undoubtedly improve the predictive ability of the model.

The following example is presented to help clarify the mechanics of the model and to demonstrate its potential value to the planner.

Illustration of Model

Figure 3 is a diagram of a four-area hypothetical metropolitan region showing the existing population, employment, vacant developable land, and the travel times between areas. Estimated growth for the region by 1965 is 2,000 more people and 1,000 more jobs. The distribution of residential development will be determined for each of the following cases:

Case I. The travel times between areas are the same in 1965 as at present and the increase in employment takes place in Zone 1.

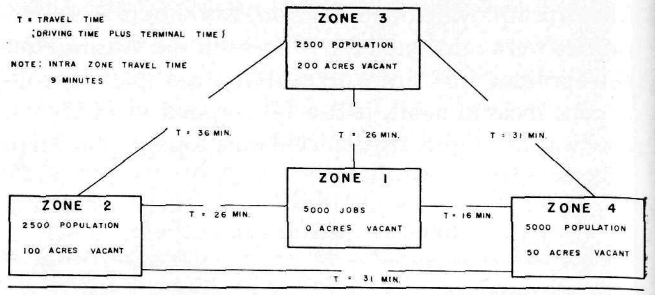
Case II. By 1965 an express highway is built between Zones 1 and 2 reducing the travel time from 26 minutes to 21 minutes. The increase in employment takes place in Zone 1.

Case III. The travel times between zones are the same in 1965 as at present and the increases in employment takes place in Zone 3.

The calculations in Figure 3 demonstrate the potential value of this and similar land use models to the city planner. The model can assist the planner in assessing the probable effects of a given action; such as the construction of an express highway (Case II) or a policy of decentralizing employment (Case III). This determination of consequences need not be limited to some predetermined area of "influence," but can easily be assessed for the entire metropolitan region.

It should be pointed out that the reliability of this model for estimating purposes is very sensitive to the quantity of development being distributed. The model is only capable of distributing fairly small increments of growth in a single application. The reasons for this limitation are quite apparent when it is remembered that the pattern of accessibility is constantly changing through time, and, furthermore, that the accessibility and the availability of developable land at any point in time is in part dependent upon the distribution of growth during the immediately preceding period.

This does not mean that the model cannot be used for long range forecasts; quite the contrary. When combined with knowledge concerning the probable density of development in each area, successive applications of the model can integrate time or synthesize metropolitan growth up to any point in time. It is for this purpose that the model when sufficiently refined, offers its greatest potential value. It will allow the planner to assess the accumulated consequences through time of a given action taken at a given time. For example, it would be possible to determine the timing and sequence of constructing an expressway system which would best promote a desired distribution of metropolitan population.



Area number	Accessibility to employment (A_1)	Dev't ratio*	$D_1 C_1$	% of total Dev't†	Res. pop. increase (P_1)
CASE I					
2	$\frac{6000}{26^{2.2}} = 6.3$	145	14,500	14.7	294
3	$\frac{6000}{26^{2.2}} = 6.3$	145	29,000	29.5	590
4	$\frac{6000}{16^{2.2}} = 13.3$	1100	55,000	55.8	1116
Total			98,500	100.0	2000
CASE II					
2	$\frac{6000}{21^{2.2}} = 7.5$	230	23,000	21.5	430
3	$\frac{6000}{26^{2.2}} = 6.3$	145	29,000	27.1	542
4	$\frac{6000}{16^{2.2}} = 13.3$	1100	55,000	51.4	1028
Total			107,000	100.0	2000
CASE III					
2	$\frac{5000}{26^{2.2}} + \frac{1000}{36^{2.2}} = 5.7$	110	11,000	4.1	82
3	$\frac{5000}{26^{2.2}} + \frac{1000}{9^{2.2}} = 13.3$	1100	220,000	82.0	1640
4	$\frac{5000}{16^{2.2}} + \frac{1000}{31^{2.2}} = 11.6$	750	37,500	13.9	278
Total			268,500	100.0	2000

* ($D_1 = A_1^{2.7}$) † ($D_1O_1/\Sigma_1^N DO$).

FIG. 3.—Hypothetical Example: Application of the Accessibility Model

The immediate value of the relationships described in this paper is that it will be possible to isolate and examine empirically the effect of other factors on land development, such as income, zoning, taxes, and land costs. The results of such studies would provide the planner with a clearer understanding of the metropolitan community and of the effectiveness of land controls. The results of these studies could also be incorporated into the present model.

Although additional research and refinement are required, the approach described here can provide the city and transportation planner with a valuable tool.

ARTHUR ROW and ERNEST JURKAT

The Economic Forces Shaping Land Use Patterns

This urban land use model is based on the thesis that all activities in urban areas depend on convenient proximity to certain other activities. The owner of a business activity tries to minimize transportation costs to his outlets by minimizing distance. The relative competitive economic strength of activities is a major determinant of their locational patterns. The ability of any activity to compete for a good location depends on an income-density combination. If population, economic composition, household incomes, business incomes, and input-output patterns of business are known, a generalized land use projection can be constructed.

Virtually all urban functions or activities require proximity to certain other activities. Each function has a certain set of needs: the manufacturer needs materials, market, and labor; the resident needs employment, shopping, schools, etc. Generally speaking, any activity seeks to minimize the distance requirements for these in-puts and out-puts. Distance is a cost. Some activities minimize distance by locating at the center of an urban area, for example, the specialized activity characterized by very few establishments whose customers are distributed throughout the entire urban area. Others minimize distance by distributing themselves throughout the urban area in close proximity to their customers, for example, the activity characterized by many establishments serving households directly, such as convenience goods stores.

As business activities move toward the center of the area, distances are minimized, but competition for existing urban land is increased. Familiar to city planners is the curve of residential density plotted against distance from the center. Table 1 provides a simple example of this in three cities.

TABLE 1

Comparison of Residential Density at Selected Distances from the Center in Three Metropolitan Fields

Distance from Center in miles	Density per Square Mile		
	Philadelphia	St. Louis	Houston
2	32,000	31,000	9,600
5	10,000	8,700	3,250
10	2,030	1,580	133

It is evident that in constructing a land use model, an important factor to be considered is the relative competitive ability of all activities to acquire space. This competitive ability depends first on income.

Obviously, the ability to pay rent for the space required by the activity depends on both the income of each unit (residential household or business worker) and on the number of these units which can effectively operate on a given parcel of land. In effect then, it is postulated that competitive ability to acquire space is the product of business-income-per-worker[1] times employment density, or the product of household income times residential density.

The space requirement for an activity must be measured vertically as well as horizontally. Both dimensions are critical in making space or density estimates. To illustrate, the range of square feet per worker in the women's apparel industry is small, clustering about 100; further, as many as ten floors can be stacked vertically for efficient operation.

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[1] Gross profit plus wages and salaries divided by the number of workers.

If business-income-per-worker is related to worker densities by business type, the result can be expressed in terms of income per unit of land, for example as income per acre or as income per square foot. Similarly, a combination of family income and residential density can be prepared. Several empirical studies have shown that family income tends to rise quite regularly as residential density decreases to a certain point where income then decreases with density. There is an exception at the very center in some cities where income increases again, a phenomenon which is becoming more typical.

If arrays of business income per unit of land and residential income per unit of land are prepared, a considerable parallelism should be evident. A limited number of business activities can out-compete households for land, but for most of the array the figures would be comparable. Those business activities which can outcompete are those which tend to locate in the core of the downtown area.

Since competition for land increases with its accessibility to the center and to all other land, an urban area can be divided into units grouped according to equal time distance from the center. In an abstract situation this would mean subdivision of the total area into rings of decreasing densities. If the arrays of income per land unit are subdivided, then the resultant groups can be allocated to these rings either empirically or hypothetically. Thus in each ring there would be a certain amount of employment and a certain amount of residence. Such a grouping can serve as a very general conceptual framework for distributing all activities in space.

In order to demonstrate this, a simple illustration may serve. Picture a middle-income neighborhood with 10 dwelling units to the acre. If the average family income is $6,000 a year, then the income is $60,000 per acre. Now picture a low-income neighborhood near the city center with a density of 75 dwelling units per acre. If the average family income is $2,000, then the income per acre is $150,000. In other words, the second income-density combination can compete more effectively for land than the first.

A simple model based only on the material presented to this point makes no provision for separation of uses, except on an income basis. Thus such a model would imply a mixture of uses in our hypothetical ring. Of course, a good deal of such a mixture actually exists in cities. And even in a completely planned city, some mixture would be inevitable; for example, the convenience store located in a residential neighborhood or the doctor's office maintained in his home.

On the other hand, a general pattern is observable in existing cities in which some areas are dominated by business uses and others by residential uses. If there were a completely random mix in each ring, of course residence would dominate the scene because it is the biggest land user. What occurs is that certain clustering tendencies of various business types produce nonresidential clusters. The economic basis for this is reduction of distance cost either because there is an interplay or linkage between activities or because there are certain facilities used jointly by the activities.

It has been asserted that as the center is approached, increasing rent requirements are met by a combination of income and density.

Income can be used to pay for ground rent or transportation; more precisely, the spender seeks a balance to meet his needs. Just as distance produces a cost, specific expenses are associated with density. Each activity has density tolerance limits.

Using residence as an example, a typical household has a certain set of requirements. These include employment, goods and services, the satisfaction of social and spiritual needs, and amenities. For most households, employment requirements are best met where opportunities are greatest, that is, toward the urban center. On the other hand, for most families open space ranks high in the list of amenities and this is best met toward the periphery. Thus there is established a strain between opposite pulls. But the relative strength of the two pulls is unequal; livelihood is the primary need. Hence, as income decreases, the amount of the family budget that can be allocated to the distance costs implicit in the amenities direction is less. Therefore, low-income families can generally be expected to increase toward the center. In order to meet the land-rent requirements, low income must be combined with high density. This combination of factors is a major determinant of the density gradient. A major factor then in shaping this gradient is the curve of family-income distribution. Density gradients for three metropolitan areas are shown in Figure 1.

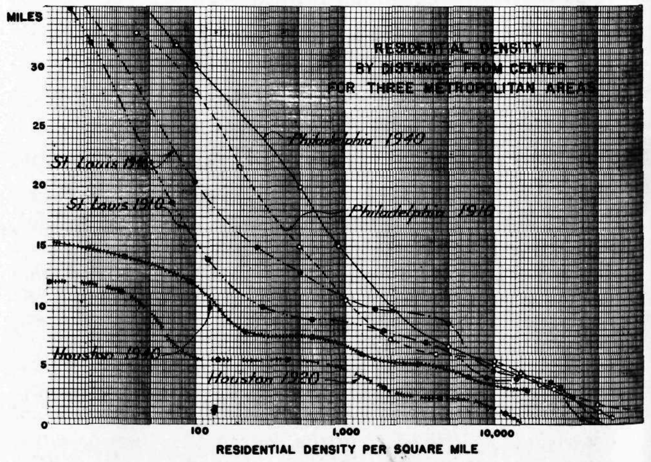

FIG. 1.—RESIDENTIAL DENSITY BY DISTANCE FROM CENTER FOR THREE METROPOLITAN AREAS

For residence there are of course different density tolerance limits according to family composition. Thus a certain natural selectivity takes place in which both income and density tolerance are at work.

Nonresidential activities are also subject to pulls. Classically, these are grouped under the headings of labor, market, materials and services. As in the case of the household, income can be used to pay for ground rent or for transportation. Thus a firm with highly specialized labor requirements would tend to seek a location at the center or in proximity to a residential area in which these labor requirements were adequately met; the major factor in the location decision made would be the rent-paying ability in combination with density tolerance.

In the apparel industry, for example, labor force requirements are a dominant location factor and are most satisfactorily met close to the urban center. Furthermore, the density tolerance of this industry is high, both because space per worker can be small and because the industry can operate effectively in multistoried buildings. In some research laboratories, on the other hand, the labor force requirements are best met in proximity to residential areas of middle to high income, and density tolerance is frequently low. A food processor may experience a dominant pull in distribution for the local market and secondary pulls in the source of raw materials and labor requirements and would seek a location where he could reasonably balance distribution (transportation) costs and his rent-paying ability. His density tolerance would be elastic within certain limits.

In addition to the pulls discussed above for business activities, establishment size is a major factor that cuts across all of them. Establishment size places significant restrictions in location on all activities. The small firm may have to locate in high-rent areas in order to obtain certain services that are not available internally. A very large concern, on the other hand, has a large degree of independence concerning location because of its attractive power to employment and its ability to provide many of its own service requirements. Further, of course, the large concern faces difficulties of land acquisition as it approaches the center.

Theoretically then, each activity can only operate across a limited location range.

In order to construct a model for an urban area, it follows from what has gone before that we should know:

a) population (by household)
b) household income distribution
c) employment by industry type
d) business income distribution on a per worker basis by industry type
e) establishment size distribution by industry type
f) local transportation system
g) land and building supply

We should also know or be able to infer from the material given above:

h) residential density range and gradient
i) worker density range by industry type

Finally, we should know:

j) input-output pattern of each business type in terms of its labor requirements, its materials and service requirements, and its market.

This last set of data (j) provides a basis for inferring the linkages between activities that lead to agglomerations. This in turn provides a basis for separating the nonresidential from the residential areas.

Even with these data, some variety of patterns within the over-all framework is possible, considering the data limitations and the inherent difficulties involved in model construction, not to mention the differences in local objectives. A major difficulty is in determining the size, shape, and number of industrial and business areas, although it is believed that these would generally take the form of sectors. There would be nodes at transportation intersections and some distribution along circumferential transportation facilities.

Other important factors which further limit the variety of patterns, and which must be evaluated in the process, are (with examples):

a) physiography—the effects of terrain and particularly of rivers
b) the existing development pattern—the effects of a transportation system or major unique installations
c) social factors—the effect of racial prejudice
d) local public policy—the effect of zoning

These factors can be utilized in one of two ways. Either they can be used to explain deviations from a model or they can be inserted into the model. Which course is taken depends upon the purpose for which the model is being built.

To be useful to the city planner a model should be predictive. Thus it is necessary to make forecasts of the data inputs described in (a) through (j) above. Making these forecasts requires assumptions as to national policy and estimates of future interregional economic relationships. This of course is a subject on which much is being written today. In this paper it is simply assumed that reasonable forecasts are available or can be made.

Two analyses presently under way for forecasting purposes are worth noting. The first is an analysis of economic composition of cities by size, which permits drawing certain conclusions regarding the probable directions of economic growth for cities at different stages of development. The second is an analysis of trends in productivity which permit inferring the directions of productivity change by industry. This is of particular importance because it affects industry size, income per worker, and density, all major determinants to location.

How then can the planner assemble a useful working model? In most situations the planner is not planning an urban area from scratch on a flat plain. He is trying to orient future development of an existing city and to reconstruct those parts that are worn out. He wants to bend the development toward an ideal, but he needs a device that will signal to him if certain proposals exceed the bounds of theoretical reality. He must predict, but his responsibility is a plan not a prediction. He must avoid calling probability his objective, but he must recognize that probability affects his objective. How then does he go about constructing a model; and, perhaps a more precarious task, how does he use it?

It should be clear from all of the foregoing that there are a number of different tasks involved. There is no magic sequence to the order in which they are undertaken. Some can be prepared simultaneously. In any case there has to be feedback and revision.

The planner can start by examining the urban area in gross terms, the terms dictated by the major forces we have hypothesized are shaping the city: the sheer size in population and jobs and in its areal extent; the land in residential use (including its nonresidential ancillary activities) and its density and income pattern; the land in nonresidential use and its activity *and* density pattern; and the transportation system. Subdivided into units for purposes of comparative measurements, based upon effective distances from the center, certain distortions in the development pattern would be evident. Some predominantly residential areas would have a lower population density than would be expected for their effective distance from the center.[2] We may hypothesize that these areas are most subject to change if some new force is injected into the situation. We can note them as areas of most probable development.

The planner must examine the recent past. In the paragraph given above we were looking at the city "as is." Actually of course the city never "is." It is a cliché to say that the city is dynamic; it is also correct. If the relative growth rates of the different subareas are computed, those where continuing development may be expected and those where a changing trend is imminent may be noted. The planner should inspect those areas whose growth rates are less than would be expected for their effective distance. If the land is swampy, the reason is obvious; but at some point in urban development it may become economic to fill the land. Or the area may be changing from residential to nonresidential development. Or the land may be being held down in development for one of several possible reasons. At any rate, it will be evident that there are certain zones which have significant development potential.

Then the planner must estimate future growth potential in terms of population and jobs by type. The word "potential" is used advisedly; future growth within a range is dependent upon local development policies. For working purposes in the model, growth potential must be expressed in numeric terms. Thus a set of numbers is selected with the knowledge that these can vary within certain limits for a selected time period. These numbers for population should include household size and income. For employment they should include industry type, establishment size ranges, income, and density ranges.

There is then a situation ready to be triggered: an urban area in some state of disequilibrium, certain of its parts susceptible to imminent change, and a future potential pressing.

An important task of the model builder is to set up the planning hypotheses for the future time period for which he is concerned. There is an infinite variety of combinations of hypotheses, ranging from the unreal state of "no change" (i.e., no new transportation, no urban redevelopment, no changes in zoning, no change in tax policies), to an equally unreal state of total change in these same fields.

The single most important hypothesis is the transportation system. This changes the effective distance relationships between all zones and the center and between the zones themselves. With such a change, the development potential of each zone is changed. Into these zones new figures would be plugged.

Next comes the question of development policy. Here the planner has two choices of action. He can insert those policies extant at the time, such as urban redevelopment; or he can inspect his model and make some educated choices as to an appropriate urban redevelopment policy. Let's assume he chooses the former. The model then tests his policy at this point. It may be evident that the urban redevelopment policy he is inserting is contradictory to the forces set in motion by the transportation hypotheses: for example, a proposal to reduce radically the density in an area whose relative effective distance is significantly improved by the transportation insert. Urban redevelopment of course is not the only form of development policy. Zoning is another. Promotion policies are another. These general policies must be reduced to numerical terms for insertion in the model.

Another area of hypothesis is tax policy. Traditionally this has lain outside the scope of the planner's responsibility, but in certain cases alternative assumptions may have a significant effect on development pattern. Assessment policies in downtown areas are a case in point.

A model such as that described in very general terms in this paper has a variety of uses apparent to the city planner. For certain purposes the planner needs a complete and internally consistent model of land use which accounts for all projected population and activities in space; preparation of the long-range transportation system plan is an example. For other purposes, however, it is of considerable value for the planner to know the direction of change, even if a set of ultimate numbers may vary widely from the eventual fact. Determination of general redevelopment objectives could be more satisfactorily made if direction of change were apparent.

A model is a device for systemizing knowledge in a useful and manageable form to increase the planner's awareness. The ramifications of development proposals are so widespread that awareness of effects cannot be left solely to intuition.

If the planner is aware of the component parts of his model he can make changes in certain of these parts with confidence in both their probable effects and their feasibility. For example, knowing the income-density relationship at any point on the curve from center city out he can make radical changes in the density in a given zone if he designs it so that the income level is also changed. If he designs it for one without the other, then he is establishing a situation which will be under considerable pressure for change over time, unless he is prepared to underwrite a continuing subsidy.

The planner deals with three separate areas of ideas: forces shaping the community; planning hypotheses; objectives. He needs all three to prepare a plan. He needs all three to prepare and evaluate a working model. But he must keep the three clearly separate in his mind and in his model. The model cannot dictate policy. It can show the planner what problems he has to cope with in achieving his ends under certain explicit planning hypotheses. It is a means to assist in the preparation of a plan. And, after all, the plan itself is only the means to an end.

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[2] Frequent reference to effective distance from the center may appear to be too all-inclusive a concept to some. What about the sector theory? There is no conflict. It has been pointed out that some areas tend to develop into nonresidential uses, others residential. There is no reason why this should not occur on a sector basis and in fact to some extent it does. Further there is no reason why a particular sector should not develop into a higher income sector than another. If a sector so develops, it is consistent, provided that the combination of density *and* income is comparable with other areas for comparable effective distances; thus one would expect the subareas in the higher income sector to be developed at lower densities.

WILLIAM B. CALLAND

Traffic Forecasting for Freeway Planning

A traffic model was employed in the San Diego area for the purpose of designing the proper freeway system. Following the basic gravity concept, this model relates trips between zones to total trips generated by each zone and to the distance between those zones. The mathematical influence that distance and trip generation have on travel patterns is determined by analyzing the data obtained from a comprehensive home-interview study. Tests of the procedure reveal a maximum error of 15 per cent for large volumes of traffic.

THE CALIFORNIA DIVISION OF HIGHWAYS for many years has emphasized the importance of systematically forecasting future traffic volumes in highway planning. These forecasts are one of the major factors affecting highway location studies and are singly the most important factor in intersection and interchange design.

Prior to the construction of freeways, state highways in urban areas were conventional major city streets, and improvement to these thoroughfares engendered little change in the regular traffic pattern. Highway engineers, in estimating future traffic volumes on such arterials, depended on trend data based on previous traffic counts. But when new freeways which attract the traffic away from many parallel streets began to replace major arterials the trend method proved obsolete.

Since traffic volume forecasts for a freeway system within an urban area must reflect anticipated land use development, the combined efforts of both city planners and engineers are essential. The planner determines future population and land use for undeveloped portions of the study area; the engineer evaluates trip generation and travel patterns for the total population.

Travel patterns have been the subject of intensive study by the California Division of Highways in the past few years. Analysis of origin and destination survey data continues to support the proposition that travel is predictable and can be related to purpose, time, distance, and trip generation. It has been found also that travel between two specific areas can be predicted as a function of the trip generation of the two areas and a composite factor of the other variables called travel friction. Trip generation is a term used to describe the number of trips begun in an area. For example, a single-family residential area might "generate" 20 trips per acre. These trips would begin in this residential area irrespective of whether they ended inside or outside the region. Usually trip generation is expressed as the number of trips related to an acre of a specific type of land use. Present interarea travel friction can be calculated from the data obtained by an origin and destination survey, namely, interarea volume and trip generation. The traffic model combining these functions in equation form is the key to successful prediction of future travel patterns.

The San Diego Traffic Model

The procedure for forecasting future traffic volumes for a planned freeway or freeway network has been largely standardized by the Division of Highways. Probably the most important and difficult step is the preparation of a table indicating the number of trips that will be made between various zones in the metropolitan area. Such a forecast may be calculated by using a traffic model.

The traffic model developed in the San Diego metropolitan area by the Division of Highways parallels the basic theory of gravitation conceived by William J. Reilly in 1929.[1] Reilly stated his law as follows: "Two cities attract retail trade . . . from an intermediate city or town in the vicinity of the breaking point, approximately in direct proportion to the population of the two cities and in the inverse proportion to the square of the distances from these two cities to the intermediate town." Where Reilly's model has population and distance as the components of the equation, the San Diego model has trip generation and travel friction as the components. The model states that the volume of trips from a zone of origin to a zone of destination is equal to the product of trip generation in zone of origin, trip generation in zone of destination, and relative travel friction.[2]

An earlier traffic study that provided data on travel characteristics for the San Diego area was a comprehensive home-interview type origin-and-destination survey conducted in 1952–53. Travel characteristics resulting from the study proved invaluable in developing the San Diego model. Through this study it was possible to determine relative travel friction factors for each interzonal movement.[3] Factors could be calculated, since interzonal volume and trip generation for each traffic assignment zone had been identified. Therefore, each interzonal transfer was divided by the product of the trip generation of the origin and destination zones.

The first step in this process was the calculation of relative travel friction factors for all interzonal movements occuring during the 1952–53 O-D survey. Then it was necessary to correlate these friction factors with some function of travel, for example, time or distance. Since the objective of the San Diego study was to establish a freeway network to suit the travel desires resulting from future population growth, it was reasoned that the function of travel to be correlated with the travel friction factor must be independent of the road network.

The method proposed for determining this network was: (a) assign traffic to a study plan; (b) analyze the deficiencies of the plan; and (c) if necessary, make subsequent traffic assignments to modified plans until a balanced network is obtained. Because the ultimate objective was to provide a freeway network to meet future travel desires, all functions of travel dependent upon the network itself were discarded. Air-line distances between zone centers were correlated with relative travel frictions. Investigations revealed that trip purposes must also be considered; hence, four curves were developed, one for each of the following categories:

1. Trips with either origin or destination outside the metropolitan area
2. Trips with both origin and destination within the downtown area (central business district)
3. Trips with either origin or destination within the downtown area (CBD.)
4. Other interzonal trips

Excepting category number 2, all plots relate travel friction to air-line distance between zone centers. The plot for category number 2 is travel friction factor versus street distance between zones in the downtown area.

An important factor in developing this projection technique was that a large percentage of the possible interzonal movements was zero at the time of the O–D survey. A designation of only 80 zones within the metropolitan area yielded zero interzonal volume for 49 per cent of the possible movements. Therefore, if any future study were undertaken it would be necessary to predict independently new relative travel friction factors for all the possible interzonal movements.

Intrazonal Trips

Before the forecasting of interzonal volumes was started, two additional calculations were required: the determination of intrazonal trips for each zone; and their subtraction from the total number of trips. (An intrazonal trip is one having both origin and destination within the same traffic assignment zone.) An analysis of origin-and-destination data indicated that the following factors affect the percentage of all trips generated within a zone that terminate within that same zone.

1. Area of the zone
2. Ratio of developed area to total area
3. Type of development (residential, commercial, industrial, etc.)

Factor number 2 was discounted in the forecast, for it was assumed that the entire area within the cordon would be developed and that redevelopment would be progressing in other areas. Since a land use survey was not made in conjunction with the O–D survey, it was impossible to relate the amount of intrazonal traffic to the type of development. It was possible, however, to measure development in terms of the number of trips per unit area— in effect, trip density.

In thoroughly developed areas, zones having a low

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[1] William J. Reilly, *The Law of Retail Gravitation* (2nd edition, New York: Filsburg Publishers, Inc., 1953).

[2] The model in equation form:

$$V_{1-2} = KT_1T_2f_{1-2}$$

where

V_{1-2} = Volume of trips with origin in Zone 1 and destination in Zone 2,

T_1 = Trip generation in Zone 1,

T_2 = Trip generation in Zone 2, and

f_{1-2} = Factor denoting relative travel friction.

(This f_{1-2} factor is the same as $\frac{1}{T^{x}_{1-2}}$ used in the typical gravity model discussed in Hansen's article.)

K = Constant of proportionality.

[3] Actual friction factor is 10^{-6} times all numbers shown on charts.

trip density usually had a low percentage of intrazonal to total trips. Low trip density zones were largely residential. As trip density increased, the additional trips usually were associated with commercial or industrial development. And, except in industrial zones, the percentage of trips that were intrazonal was generally higher.

Industrial centers generate large volumes of trips per unit area, primarily trips of the longer work-to-home type. A low percentage of these trips is intrazonal. Thus, it was decided to forecast intrazonal trips for industrial zones by using the relationships observed during the O–D survey. The remainder of intrazonal travel was established on the basis of size of the area and trip density for each zone (see Figure 1).

Interzonal Trips

After determining intrazonal trips for each zone except in the CBD, interzonal volumes were forecast using the following procedure.

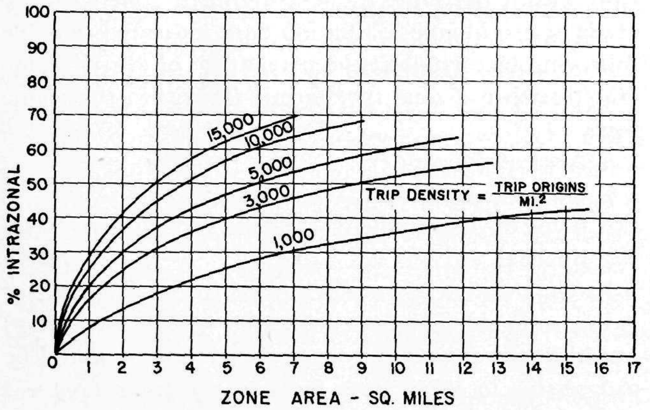

FIG. 1.—Percentage of Zonal Trips Made Within the Zone

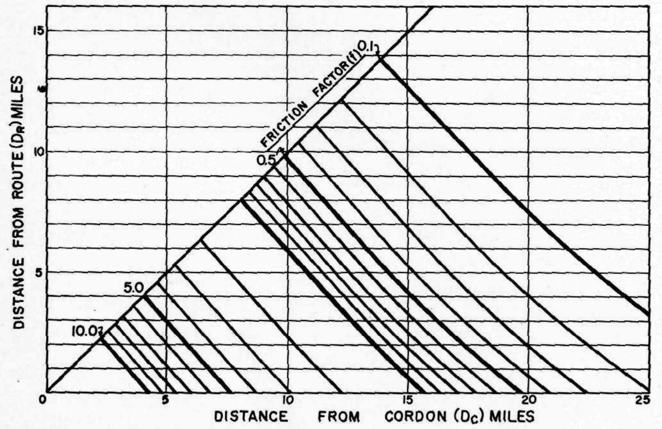

FIG. 2.—Cordon Station Friction Factor

D_C = Air-line distance from Zone to cordon station

D_R = Air-line distance from Zone centers to nearest freeway route providing access to cordon station

Step 1. Determine the number of trips with origin and/or destination outside the cordon which encircled the metropolitan area. Trips entering the area (one half total volume) at each cordon crossing are then distributed to the various zones using the gravitational equation and friction factors provided in Figure 2.

Step 2. Determine the number of trips with both origin and destination within the CBD. Total percentage of intrazonal trips within the CBD was assumed to remain the same since no major change in the land use pattern is expected. After deducting intrazonal trips for each CBD zone, interzonal trips *within the CBD* are forecast using the gravitational equation with friction factors measured in Figure 3. Subsequently the remainder of the CBD trips is distributed to other zones using friction factors from Figure 4.

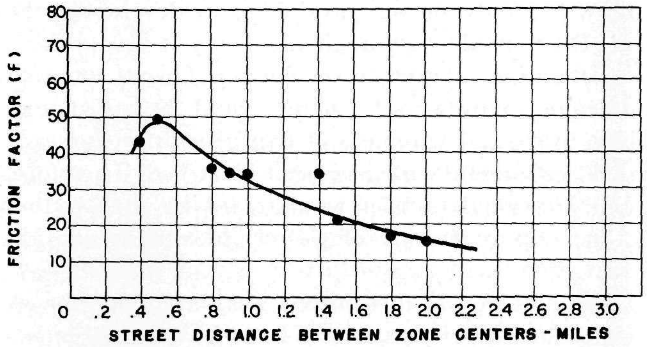

FIG. 3.—Intra-CBD Friction Factor

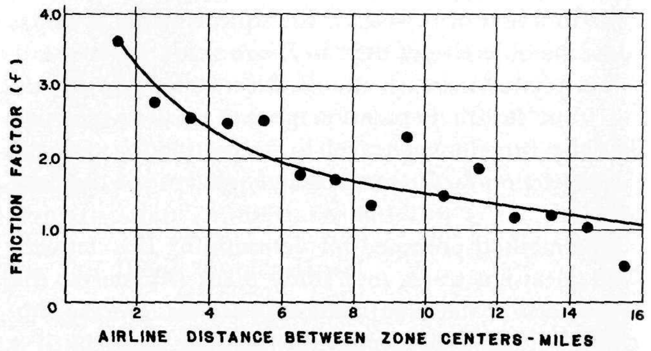

FIG. 4.—CBD-to-Zone Friction Factor

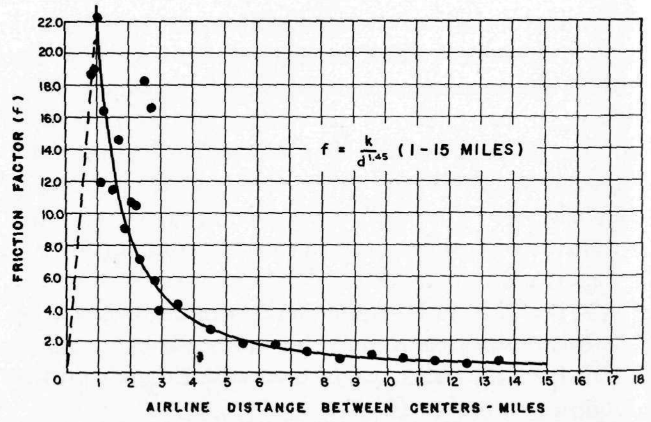

FIG. 5.—Interzonal Friction Factor

Step 3. Predict the remainder of the interzonal volumes using the gravitational equation and friction factors in Figure 5.

Before accomplishing each step, the trips distributed in previous steps were deducted from the total number of trips generated in each zone.

Steps 1 and 2 were implemented manually. Both steps ordinarily represent a small percentage of the total interzonal movements. Step 3 was executed by using an IBM 650 electronic computer.

Discussion of Procedure

After distribution of the trip origins from any zone in Step 3, it is immediately apparent that the total volume of distributed trips to each zone does not equal the number of trips assumed originally to be generated by each zone. This inequality occurs because the travel friction factors realized from Figure 5 are the composite functions of many zonal movements and therefore are not specifically applicable to any individual zone. The position of the zone within a metropolitan area greatly affects the distance of travel by trips originating in that zone. For instance, a zone near the cordon around the metropolitan area is usually surrounded by zones which generate relatively few trips and the distances between the zone of origin and all possible zones of destination are greater. The opposite is true of a zone near the center of the metropolitan area.

The curve in Figure 5 can be stated mathematically as $f = K/d^{1.45}$ for distances of from one to fifteen miles; therefore, the distributed volume of trips from any zone can be modified to equal the original estimate of total trips by adjusting the value of K (constant of proportionality). This adjustment will not alter the ratios of magnitudes of interzonal volumes originating in a particular zone, since the first derivative of the relationship between travel friction and air-line length of trip remains constant. As an example, assume that the total number of trips remaining to be distributed from Zone 1 for Step 3 is 5000 and that after calculating the volumes between Zone 1 and all other zones, the individual volumes total 5,500. The magnitude of the value of K for each interzonal movement originating in Zone 1 is then adjusted by a factor of 5000/5500.

The adjustment of this K value for each zone creates a new problem inasmuch as the predicted interzonal volumes between any two zones are no longer equal by direction. When combined into triangular table form, this imbalance by direction is not apparent because interzonal volumes are generally believed to be two-way volumes and equal by direction. If this assumption is valid, one half the total interzonal volumes associated with any particular zone does not equal the original estimate of trips originating in that zone. An iterative procedure then must be used to bring the triangular table into balance. In the San Diego study, however, none of the calculated triangular tables were unbalanced to the extent that application of the iterative procedure was considered necessary.

Accuracy of the Model

To determine the precision of the model, two separate traffic assignments were made to the same major street and freeway plan. The first assignment was based on interzonal volumes obtained from the O–D survey. The second assignment based on theoretical interzonal volumes as calculated by the gravitational method previously described. The deviation of freeway segment volumes obtained from the gravity model from those derived from the O–D data indicated the magnitude of error which might be expected when projecting traffic.

In calculating the percentage and absolute error for each of the 220 segments, volumes were grouped and plotted against average daily traffic. Figure 6 presents the comparison of error by volume groupings. (The mean error signifies a 50–50 chance that the error will be less than indicated; while the root-mean square error denotes that two thirds of the time the error will be less than indicated.) In these calculations, all errors were attributed to the theoretical assignment. Over 20,000 average daily trips (ADT), the percentage error becomes more nearly constant. Normally, few freeways will be built to accommodate less than 20,000 ADT.

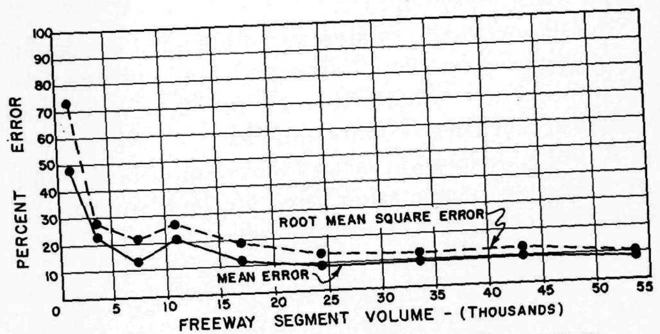

FIG. 6—Percentage Error for Freeway Segments of Different Volumes

For engineers, the comparisons of absolute volume errors shown in Figure 7 are most pertinent. Errors of from 3,000 to 5,000 ADT for freeway volumes ranging from 20,000 to 60,000 ADT are insignificant when figuring the number of freeway lanes. In California, the difference between practical capacities of urban 4- and 6-lane freeways is about 30,000 ADT, and between 6- and 8-lane freeways from 40,000 to 50,000 ADT. The precision of theoretical assignment was within the limits required for practical application.

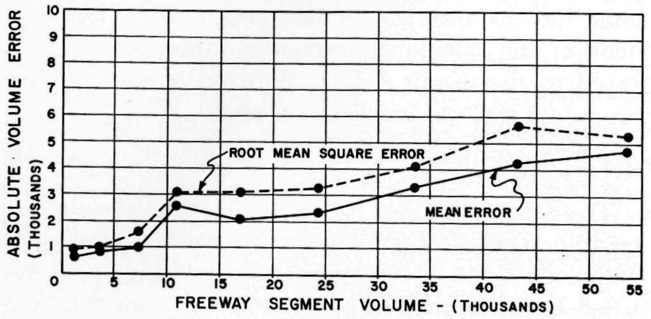

FIG. 7.—ABSOLUTE VOLUME ERROR FOR FREEWAY SEGMENTS OF DIFFERENT VOLUMES

Developing the Highway Plan

The development of the San Diego metropolitan area freeway system represents the combined efforts of city officials in the cities of Chula Vista, Coronado, El Cajon, Imperial Beach, La Mesa, National City, and San Diego, the County of San Diego, and the California Division of Highways.

A brief summary of the process used in developing the system follows.

1. The existing State Highway network served as the foundation for the proposed freeway network. To alleviate future capacity problems and serve new centers of traffic generation, additional freeways were added to the existing system.

2. The metropolitan area was subdivided into traffic assignment zones. Population and land use data for these zones were obtained from the planning departments of San Diego county and city.

3. Traffic-generation factors were established to predict future trip generation based on the planning data (see Table 1). These factors were developed by the San Diego Transportation Research Department in cooperation with the California Division of Highways.

4. From this estimated trip generation, the number of intrazonal trips for each traffic assignment zone was predicted.

5. Interzonal travel was calculated using the gravitational equation for each of the four basic trip types; CBD., intra-CBD., outside the cordon, and the remainder of interzonal trips.

6. Future traffic was then "assigned" to the proposed network of freeways and streets. This step made it possible to estimate the number of vehicles using the various segments of the highway network. The California Division of Highways procedure was followed.[4]

TABLE 1

FACTORS USED TO FORECAST TRIP ORIGINS IN THE SAN DIEGO AREA, AVERAGE WEEKDAY

Type Area	Factor (No. origins)
Residential	*per dwelling*
Less than 1.0 vehicles per dwelling	2.7
1.0 to 1.5 vehicles per dwelling	3.2
Over 1.5 vehicles per dwelling	3.7
Commercial	*per net acre*
Mature trend areas and strip development	215
Community and regional shopping centers	275
Central Business District	
Central retail core	700
Professional district	550
Mixed commercial district	250
Industrial district	180
Industrial warehousing district	100
Apartment district	200
Schools	60
Industrial Areas	
Aircraft plants	
a. without parking	180
b. with some parking	110
c. parking provided	60
Modern industrial parks	65
Research parks	35
Distributional industrial districts	85
Bay front and shipbuilding districts	25
Large warehousing districts	50
Open storage districts	10

Source: San Diego Transportation Research Department.

Once the traffic assignment for the study plan was completed, problems of inadequate or excess capacity were identified. After investigating several of the turning movements, it was concluded that several routes were not properly located. Subsequent refinements were made until an efficient and balanced system resulted.[5]

The accurate forecasting of future travel patterns, it is believed, will have an important role in California's huge road building program, will contribute to that state's economic well-being, and will improve its future urban planning.

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[4] A description of this method and how it can be adapted to high-speed computer application is described by Karl Moskowitz in "California Method of Assigning Diverted Traffic to Proposed Freeways," *Bulletin 30,* Highway Research Board, 1956.

[5] Many locations where traffic service was inadequate might not have been evident had the traffic forecast been based upon projected freeway travel time or street distance.

HOWARD W. BEVIS

A Model for Predicting Urban Travel Patterns

A traffic model was developed by the Chicago Area Transportation Study for predicting urban traffic volumes. The research conducted by CATS indicates that a combination of the gravity model and a linear programming technique provides a sound method for forecasting. Linear programming is one of the newest techniques in the industrial field. It can be applied to the city planning field to indicate expected travel patterns that would result. Tests reveal that it is a satisfactory and reliable procedure for forecasting traffic.

OF NECESSITY, a sound transportation planning program must be based upon accurate methods of forecasting traffic movements. This paper explains a model developed at the Chicago Area Transportation Study (CATS) to predict traffic volumes among urban areas—an important step in analyzing transportation needs.

In order to predict future traffic volumes between zones, certain information must be available and certain principles must be observed. The number of trips generated by each zone within the study area must be predicted. In order to increase the accuracy of the forecast, these generated trips by zone should be classified by trip type. For example, trips may be classified according to purpose—work, shopping, social, recreational, and miscellaneous. Or trips may be classified according to the specific land use of their destination—whether residential, industrial, commercial, or other types.

The number of trips generated by each zone places certain limitations on the prediction procedures. The application of the model must assure that the sum of all the trips distributed from any zone will be equal to the number of trips originally assumed to be generated by that zone.

In addition to zonal trip generation, measurements of "travel frictions" must be established between and within zones to weigh such factors as time and cost of transportation that discourage travel between areas. Between-zone travel-friction indices provide a basis for estimating interzonal movement. Measurements of average travel friction within zones allow estimates of intrazonal movement.

Gravity Models

One approach frequently used in predicting urban travel is based on the gravity model. It states that all trips emanating from an area are attracted or "pulled" to various other areas. The strength of this pull is directly related to the total number of trips generated by each zone, and indirectly related to the travel friction between the areas. One of the most common refinements found helpful in applying the model involves the classification of trips—by mode of travel, trip purpose, land use, or spatial location. A multiple trip classification may be devised also. One equation, for instance, may be developed for work trips via auto; another for shopping trips via auto. A separate set of similar equations can be developed for mass-transit trips. Different exponents and constants are necessary for each equation. Then, daily travel patterns are determined by totaling the trips for various purposes.[1]

The gravity model as described above, however thoroughly refined, will not assure that the sum of the zonal interchange volumes related to any zone will equal the number of trips generated by that zone. Thus,

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[1] This is the general procedure described in the article by Booth and Morris.

it is necessary to balance these volumes. The research of the Chicago Area Transportation Study indicates that the combination of a gravity model with linear programming technique provides a sound method of achieving this balance.

TABLE 1
A COMPARISON OF ACTUAL AND ESTIMATED NUMBER OF TRIPS
(By trip length)

Trip Length (in miles)	Percentages of Trips	
	Actual	Estimated
All trips	100.0	*100.0*
0–1.9	26.2	*26.4*
2–3.9	23.4	*23.1*
4–5.9	14.5	*14.6*
6–7.9	8.9	*9.1*
8–9.9	9.9	*9.2*
10–11.9	4.2	*5.7*
12–13.9	4.3	*4.4*
14–15.9	3.9	*3.6*
16–17.9	1.4	*1.6*
18–19.9	.9	*.7*
20 and over	2.4	*1.6*

Linear Programming

Linear programming is basically a mathematical method for maximizing or minimizing a linear function of several variables subject to certain constraints. One of the most widely used applications of linear programming is in the transportation field. For example, if a firm wanted to determine the optimum size and location of its warehouses to minimize transportation and overhead costs, it could use this mathematical approach. The restraints in this case would be costs of transportation and the cost of operating different sized warehouses.

In the Chicago model, travel frictions are being minimized. Three constraints were used; the first two stated all trips generated by a zone must be equal to all zonal interchange volumes for that zone. The third constraint stated that any zonal interchange was greater than or equal to zero (there were no negative interchange volumes) and less than or equal to some capacity measure. It is this capacity measure, or upper bound, which is determined by a gravity model.

The capacity measure estimation was accomplished in two steps. First a potential constant was calculated for each zone, then the potential constant was multiplied by the ratio of the intrazonal travel frictions for each zone to the travel friction between the zones.

In estimating potential constants, only the generated trips and the intrazonal trips were considered. To accomplish this it was assumed that the product of the trips attracted to a residential area times the trips produced by a residential area, all raised to an appropriate power, multiplied by a constant would equal the intrazonal trips in the zone.[2]

Once the constant and the exponent were established by empirical test, the potential constants for each zone were obtained.

This was defined as the product of the trips attracted to a zone, raised to the predetermined exponent, times the trips produced by the residential area, raised to the appropriate exponent, each multiplied by the square root of the constant.[3]

After computing potential constants for each zone, potential measures were computed. Then the average of the intrazonal frictions related to the two zones was divided by the interzonal travel friction to obtain the appropriate ratio. It is this ratio that is multiplied by the potential constant (P_{1-2}) to obtain the estimate of the upper bound for any zonal interchange volume (L_{1-2}).[4]

Some Results

Any proposed model must be tested to determine its reliability. Although several origin-and-destination studies were evaluated, the most extensive tests were based on CATS data.

After various checks on accuracy, it was decided that a simple two-category classification of trips was satisfactory: residential and nonresidential.[5]

Zonal interchange volumes were predicted for a sample of sixty zones using simple air-line distance as the measure of friction.

Figure 1 depicts a plot of the average trip length as reported in the O–D survey against that estimated for the same data using the model. The regularity of the pattern substantiates the reliability of the model. The study reflects a trip range of from three to ten miles, and further investigation disclosed no systematic error per trip to various segments of the region.

Table 1 compares the percentage of trips in each two-mile increment as determined from the O–D survey and the model. Again, no systematic error is evident.

This model also was compared to a gravity model, and a sample of 3600 zone-to-zone movements was analyzed.[6] The correlation for the CATS model was .89 as compared to a correlation of .78 for the gravity model.

Forecasting Problems

Three principal forecasting problems must be faced.

First, inherent in the CATS model and also characteristic of others is the requirement that the planner must determine if the basic parameters remain constant over time. In this model the stability of the equation used to estimate the potential constants is important. The stability of the exponent that expresses the friction factor must be considered in the gravity model. For lack of better evidence, it must be assumed that the parameters do remain constant.

Second, the traffic patterns predicted by any model are dependent on the number and type of trips generated by the different zones. Therefore, an accurate trip generation forecast is contingent upon a sound land use forecast.

Third, predicted traffic volumes are dependent on personal freedom of movement, so precise friction measures are necessary. Although distance was the measure of friction in testing this model, other tests have proved that travel time is a good basis for prediction, perhaps better than distance. For accurate forecasts of travel time the planner needs to know the average speeds for various facilities in different parts of the city. This of course depends on transportation objectives and standards.

Because this model reflects the desire of people to minimize travel, we think it is more relevant and more accurate than *comparable* gravity models. But this model is only a step toward the ultimate goal of incorporating methods of predicting land use, zonal interchange volumes, and trip generation and distribution into a single model. Further experimentation, research, and plain hard work must follow first.

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[2]
$$T_{1-1} = C\ (T_{1R}T_{1A})X.$$
T_{1-1} is the intrazonal trips related to Zone 1. Additional subscripts R and A refer to different trip generation figures. In predicting residential-to-residential travel, for instance, T_{1R} would be the number of residential trips starting from Zone 1. T_{1A} would be the number of residential trips attracted to the zone. Figure X is an exponent and C is a constant.

[3]
$$P_{1-2} = \sqrt{C}\,T_{1R}^{X}\quad X\sqrt{C}\,T_{1A}^{X}$$
where P_{1-2} is the potential constant for residential travel between Zones 1 and 2.

[4] Thus, $L_{1-2} = P_{1-2}\,\dfrac{T_1 + T_2}{2T_{1-2}}.$

[5] The equations for predicting the potential constants for these types of auto trips are:

Residential

$P_1 = .108\ T_1^{.753}$

Nonresidential

$P_1 = .144\ T_1^{.524}$

To obtain the residential-to-residential and the nonresidential-to-nonresidential linkage potentials, the respective potentials were multiplied. The residential to nonresidential potential is derived by multiplying the residential and nonresidential potential by 3.11.

[6] The gravity model tested was not comparable to San Diego's or Baltimore's.

JAMES BOOTH and ROBERT MORRIS

Transit vs. Auto Travel in the Future

A mathematical model was recently used to estimate existing and future traffic patterns in the Baltimore region. Based on such factors as the number of people living and working in various zones, car ownership, and the travel time between zones, it was possible to estimate the origins and destinations of travel in the metropolitan area. The model was used to predict the future traffic volumes that would occur on a proposed highway system and the volumes that could be expected if specific mass-transit improvements were made. Tests of the model indicate its reliability and versatility.

IN 1957 THE Baltimore Regional Planning Council began to examine the numerous methods of evaluating the urban transportation needs of their city. Because of limited time and funds, the Council sought a quick, inexpensive, although comprehensive, method of evaluating Baltimore's transportation deficiencies.

Aided by staff assistance from the Automotive Safety Foundation, Maryland State Roads Commission, and the city's Department of Transit and Traffic, the Council was able to complete an area-wide study without using the costly and time-consuming home-interview type of origin-and-destination survey.

The Baltimore study was predicated on the belief that there had been sufficient research in the fields of traffic movement to permit the synthesis of present traffic from known land use factors. It was believed that, in turn, if existing traffic patterns could be determined from existing land use, then the same technique could be used to project traffic movements into the future.

The method of synthesizing traffic in Baltimore was founded on two simple premises: (1) that *frequency* of individual trips depends on *desires and needs* of individuals, and (2) that *modes of travel* and *trip destinations* reflect personal transportation alternatives and trip purposes. For instance, an insurance salesman undoubtedly travels more each day than does a mother with three or four small children. The mode of travel either party chooses will depend on the availability of an automobile and/or the adequacy of public transportation services. The destinations of their individual trips will depend on the distribution of land uses—the location of shopping centers, industrial and commercial areas, and residential neighborhoods. These principles might be summed up as a "theory of opportunity."

Trip Frequency

The techniques devised in Baltimore relied first on the establishment of trip frequency. Numerous O–D studies indicated that work trips are the most common type in metropolitan areas and total about 40 per cent of all trips during an average day. This percentage is higher, often 60 or 70 per cent, during peak hours.[1]

Another category of trips, those linked to commercial areas, include trips for personal business, shopping, and dining or entertaining. Most of the commercial trips occur in off-peak hours; but 20 per cent of peak-hour travel is comprised of nonwork trips linked to commercial areas.

Trips for the purpose of visiting friends have been identified as social trips. Although not very important in the whole picture, social trips have a unique characteristic in that their destination is influenced by distribution of population. These trips account for 10 per cent of the peak-hour travel and about 20 per cent of off-peak travel.

Non-home-based trips consist, for example, of salesmen in door-to-door traveling or housewives shopping from store to store. These trips represent about 15 per cent of the travel in off-peak hours, and 5 per cent of the travel during the peak hour.

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Robert L. Morris is Traffic Planning Engineer for the Department of Transit and Traffic, Baltimore, a position he has held for the past two years. Before joining this Department, he was associated with the City Planning Department and actively participated in the earlier development of highway plans for the area.

[1] Frank B. Curran and Joseph T. Stegmaier, "Travel Patterns in 50 Cities," *Bulletin 203,* Highway Research Board.

In arriving at trip frequency in Baltimore, certain modifications within these known percentage ranges were made. The commercial and social trip frequency was based on car ownership. For every 1,000 cars garaged in a residential area 900 commerical and 700 social auto trips commenced daily, and of these, 40 commercial and 15 social trips started at the peak hour. (The Washington, D.C. study revealed about the same number of return trips during the peak hours.)

Calculating work-trip frequency involved a more complicated procedure, since the number of work trips is related to employment rather than to car ownership. First, the number of transit work trips in residential areas was estimated by using the curve illustrated in Figure 1, which was based upon an analysis of 32 different O–D studies by the Eno Foundation. This estimate was then subtracted from the number of workers usually departing daily from a residential district by some form of transportation (85 per cent of labor force), indicating the total number of persons traveling by private automobile, which reflects the findings of several origin-destination studies. Using Figure 2, the number of persons per car was ascertained for each residential area. From these data, it was possible to compile the number of auto work trips starting from each residential area. To simplify computation, it was assumed work trips would be returning home during the evening peak hour.

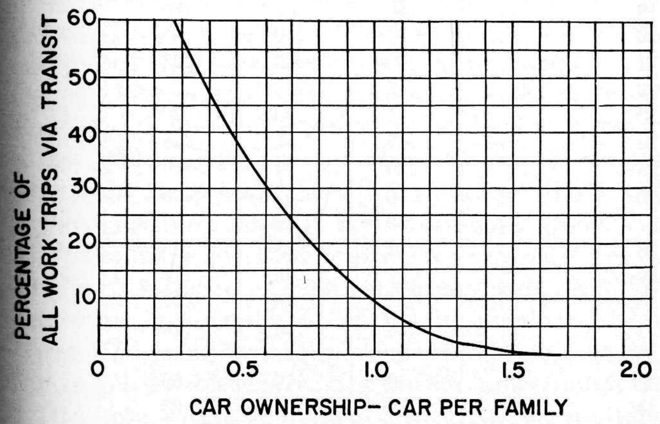

FIG 1.—RELATIONSHIP BETWEEN TRANSIT RIDING AND CAR OWNERSHIP
(Source: Highway Traffic Estimation, the Eno Foundation)

To keep the technique simple, only two types of transit trips were considered, work trips and miscellaneous trips. Since frequency of miscellaneous transit trips was assumed to be equal to that of work trips, it was possible to estimate all transit trips from Figure 1. The total number of transit travelers was calculated on this basis and was compared with the known number of transit trips for the area. (The estimate was within 10 per cent of the actual so no modifications were made.)

The foregoing steps established the mode of travel and the frequency of work, commerical, and social trips starting from a residential area. Non-home-based-trip frequency was developed at a later stage.

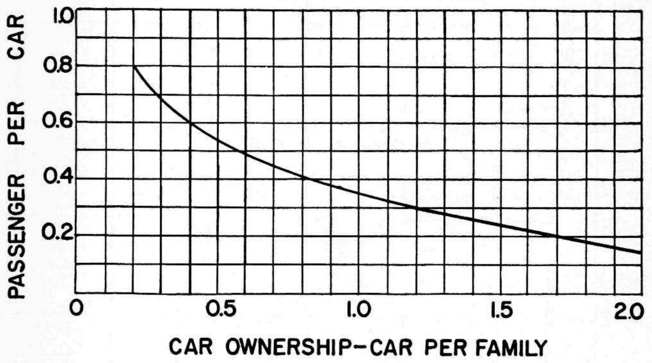

FIG. 2.—RELATIONSHIP BETWEEN PASSENGERS PER CAR AND CAR OWNERSHIP
(Based on Washington, D.C., Transportation Survey)

Trip Destination

To evaluate destinations of residentially based trips, a gravitational principle was applied. Essentially, this principle states that all trips emanating from residential areas are attracted or "pulled" to various land uses. The strength of this pull is associated directly with the size of land use development and indirectly associated with the distance (or travel time) between the land use and the residential area.[2]

Utilizing this concept for transit travel, transit time between zones was used, while auto-travel time between zones was applied for private-vehicle trips.

Transit users, of course, tend to adjust their traveling habits to accord with mass public transportation service. Travel time between zones depends upon transit service. The auto user, being more versatile, however, is influenced by the travel time permitted by the highway network. And, because most auto and transit travel occurs in the off-peak hours, mid-day hours were studied.

In selecting suitable factors to express the "size" of the attracting land use for work trips, the total number of people employed in each area was analyzed. For commerical trips, retail employment for each zone was examined to reflect the size of the attractor. This index was selected primarily as a matter of convenience, because the city planners had estimated retail employment in determining the number of workers employed in each zone. For social trips the number of people living in each area was chosen to indicate attractor size.

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[2] Alan M. Voorhees, *A General Theory of Traffic Movement,* Institute of Traffic Engineers, 1955.

The value of these factors reflects the best available data, but certain judgment decisions had to be made to fill in gaps in available information.

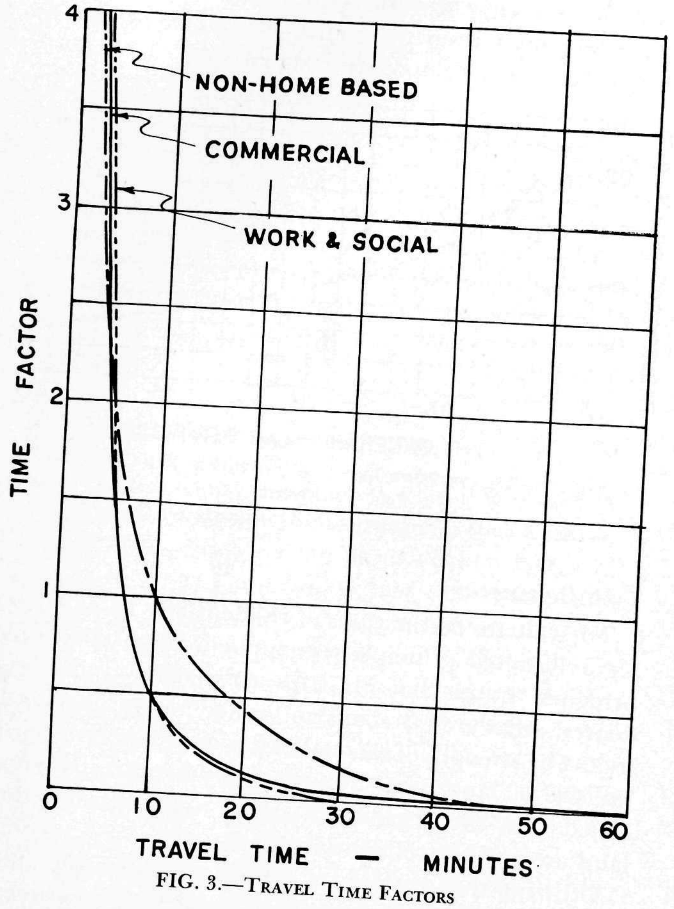

FIG. 3.—TRAVEL TIME FACTORS

TABLE 1

EFFECT OF TRAVEL TIME ON FREQUENCY OF TRAVEL

Travel Time in Minutes	Relative Frequency of Trips by Type			
	Work	Social	Commercial	Non-Home-Based
2	4.00	5.00	8.00	8.00
3	2.86	3.33	7.00	7.00
4	2.28	2.50	6.00	6.00
5	1.90	2.00	4.00	4.00
6	1.60	1.62	2.70	2.70
7	1.40	1.42	2.00	2.00
8	1.21	1.25	1.50	1.50
9	1.11	1.11	1.20	1.20
10	1.00	1.00	1.00	1.00
11	.93	.91	.80	.80
12	.86	.83	.68	.68
13	.80	.77	.57	.57
14	.75	.71	.50	.44
15	.70	.67	.44	.40
16	.66	.62	.40	.35
17	.62	.59	.35	.32
18	.59	.55	.32	.28
19	.56	.52	.28	.25
20	.53	.50	.25	.22
21	.50	.46	.23	.19
22	.47	.43	.21	.16
23	.44	.40	.20	.13
24	.41	.37	.18	.10
25	.39	.34	.16	.08
26	.36	.32	.15	.06
27	.33	.30	.14	.04
28	.31	.28	.13	.02
29	.27	.26	.12	.01
30	.25	.25	.11	...
31	.23	.23	.10	...
32	.21	.21	.10	...
33	.19	.19	.09	...
34	.18	.18	.08	...
35	.17	.17	.08	...
36	.16	.16	.07	...
37	.15	.15	.07	...
38	.14	.14	.07	...
39	.13	.13	.07	...
40	.12	.12	.07	...
41	.11	.11	.07	...
42	.10	.10	.06	...
43	.09	.09	.06	...
44	.08	.08	.06	...
45	.07	.07	.05	...
46	.06	.06	.05	...
47	.05	.05	.04	...
48	.05	.05	.04	...
49	.04	.04	.04	...
50	.04	.04	.03	...
51	.03	.03	.03	...
52	.03	.03	.03	...
53	.02	.02	.02	...
54	.02	.02	.02	...
55	.02	.02	.02	...
56–60	.01	.01	.01	...

Working with employment statistics and population figures, we found it easier to link the survey with the economic-base data for the area. From experience gained in Baltimore, we judge that it is more effective to express the size of the attractor in terms of employment and population rather than in land use acreage.

The influence of travel time on trip destination was measured by a series of factors shown in Table 1. (These travel-time factors are based on research that has shown that different factors are necessary for various trip types.[3]) Such factors indicate the effect that travel time has on the frequency of trips between areas.

Thus, to figure the destination of work trips starting in a residential zone, the appropriate time factor is multiplied by the number of people employed in various zones. Work trips are subsequently distributed to each employment zone in proportion to that zone's product and the sum of the product for all zones.

The number of non-home-based trips beginning in each zone was computed by totaling social and commercial trips attracted to a zone after employing the gravity model. In figuring non-home-based trips over a 24-hour period, the number of trips attracted to a zone for commercial and social purposes was divided by 3 to conform to the frequency pattern already discussed. The number of peak-hour trips attracted to a zone was divided by eight. The resulting compilation indicates the number of non-home-based trips starting from each area. In estimating the destination of these trips, the proportion of trips attracted to each zone for commercial or social purposes was used to indicate the size of the attractor. The time factors are shown in Table 1.

The same general technique may be used in studying truck travel in an urban area. Other studies have shown that the non-home-based-trip pattern is fairly comparable to truck movement patterns in urban areas.

Work trips were brought into balance when the gravity model was put to use. If, in its application, too many trips were allocated to a particular employment center, they were adjusted to conform to the estimated number of auto and transit trips destined to a center. This was achieved by multiplying the trips to the center by an appropriate adjustment factor. These corrective measures were applicable to work trips only.

To estimate the trips destined to an area, it was assumed that transit usage, in an employment area of low car-ownership, would be high. On the other hand, in an area of high car-ownership transit travel would be low. Trip destination was estimated using this assumption. Therefore, without empirical evidence to the contrary, we judged that Figure 1 reflected this relationship, and it was used as the basis for the necessary calculations.

The model was modified also for trips to the downtown area. It was adjusted for the difference in relationships between homes and employment of different occupational classes. (From experience in other cities it would appear that this correction is necessary only for trips to the downtown area.[4])

The correction for downtown trips was quite simple. It involved an investigation of the model's degree of error for downtown trips. (This was achieved by analyzing a previous transportation study for the CBD.)

Checks

Though the techniques used in Baltimore were based on considerable research, it was considered prudent to make certain checks on the resulting estimates. The question was asked, "Is the traffic movement synthesized through this technique an authentic picture of the traffic actually developing on Baltimore's streets?" To answer this, four screen lines were created which divided the metropolitan area into large segments. Traffic was counted as it crossed these lines and compared with the traffic estimates obtained by using the model. As indicated in Table 2, the screen-line checks were usually within 10 per cent of the actual traffic counts. Moreover, similar checks made for mass transit indicated a comparable degree of accuracy.

TABLE 2

SCREEN LINE CHECKS OF THE BALTIMORE 1958 TRAFFIC ESTIMATES

Screen Line	Actual	Estimate	Estimate As Per Cent of Actual
24 Hours			
A	487,500	457,200	*94*
B	384,900	399,100	*102*
C	323,200	365,700	*112*
D	254,400	280,900	*110*
Peak Hour			
A	40,100	40,300	*100*
B	35,400	32,900	*93*
C	30,200	33,700	*111*
D	23,000	24,100	*105*

In addition to screen-line checks, information was amassed on place of residence of employees in several industrial plants. This information was checked against estimates developed by the gravity model. As indicated by Table 3, the technique accurately portrays the proportion of trips within specific travel times of the employment area. In making this comparison on a zone-to-zone basis there was a greater deviation between the actual and theoretical estimate. For example, when zone-to-zone volumes were 100, the root-mean square error was around 50 per cent; for volumes of 1000, the error was about 20 per cent; for volumes of 10,000, the error was in the neighborhood of 10 per cent.[5] This series of checks indicated that the Baltimore traffic model was about as accurate as a 5 per cent home-interview study.

An interesting historical check was based on data from 1926, 1946, and 1958 studies which revealed home-work relationships. For this time span the gravity model was applicable if the appropriate travel time for each date was used, an especially extraordinary finding since travel times have changed drastically over the years.

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[3] J. Douglas Carroll, Jr., and H. W. Bevis, "Predicting Local Travel in Urban Areas," *Papers and Proceedings of the Regional Science Association*, 1955; also, Voorhees, *op. cit.*

[4] Alan M. Voorhees, "Forecasting Peak Hour of Travel," *Bulletin 203*, Highway Research Board, 1958.

Projections

When it was agreed that this method could adequately synthesize existing travel, the same general technique was used to project future travel. But in projecting future travel it was recognized that traffic patterns depend upon the transportation alternatives that are offered the public. Therefore, two general projections were made for 1980. The first was based upon a plan that called for extensive highway improvement with few transit changes; the second was derived from a plan that contemplated several rapid transit lines and the completion of only the interstate highway systems.

TABLE 3

Comparison of Actual and Estimated Numbers of Trips, by Travel Time from 3 Manufacturing Plants, Baltimore: 1958

Time of Trip in Minutes	Percentages of Trips Within Time Periods					
	Westinghouse		Bendix		Glenn L. Martin	
	Actual	Estimate	Actual	Estimate	Actual	Estimate
0–10	42	37	32	29	..	..
0–20	64	60	74	76	24	17
0–30	82	78	94	94	71	64
0–40	97	98	100	100	93	94
Over 0	100	100	100	100	100	100

The traffic projections for the first plan were based on the Regional Council's forecast of population and employment distribution. Car-ownership forecasting was carried out in several ways for comparative purposes. The method finally selected was based on a Bureau of Public Roads study. It showed that income of household and type of residential area had a direct bearing on the number of cars per household. The study also revealed an increase in car ownership for specific residential areas until the income level reached a range of from $8,000 to $10,000 per year. Beyond this range car ownership leveled off. This means that, in effect, there was a ceiling for car ownership for the various types of residential areas (consult Table 4). The number of cars expected to be garaged in each residential zone was estimated on the basis of trends of existing car-ownership patterns and anticipated income levels.

The existing travel times between zones were not used in projecting travel for the first plan; instead, travel times that would result from the development of an extensive freeway system were employed. This was done to reflect the fact that improved highway facilities tend to increase travel length, as revealed by the historical checks previously mentioned. In summary, the traffic forecasts considered the effects of anticipated increases in population and employment, car ownership, and expected increases in auto speeds.

The traffic projection for the transit plan was accomplished on a somewhat similar basis. Car-ownership patterns in the vicinity of proposed rapid transit lines were adjusted in accordance with Table 4. The auto-travel times between zones reflected a more limited freeway system. Certain changes were made in the land use forecasts, specifically, a 20 per cent increase in employment in the CBD.

TABLE 4

Ceiling for Car Ownership per Household

Residence Type	Autos per Household
Single Family	
new area	1.6
old area	1.0
Two Family	
new area	1.2
old area	0.9
Row House	
good transit and poor parking	0.4
good transit and good parking	0.6
poor transit and good parking	1.0
High Rise	
good transit and poor parking	0.2
good transit and good parking	0.4
poor transit and good parking	0.6

By using these criteria, a new set of auto and transit patterns was formulated. However, it was recognized that a certain portion of the population would shift from auto to transit travel in the event rapid transit lines became a reality. The estimate of the volume of this shift to rapid transit was calculated with the aid of the curve in Figure 4. The curve was applied to only 75 per cent of auto trips, that percentage of trips for which autos were not essential. It was then possible to forecast the traffic and auto patterns for the second plan.

Example

The following example is given to illustrate the application of the gravity model.

In Figure 5 the residential area designated R has 1000 families within its limits. Each family has one car. There are three commercial areas in the vicinity C_1, a mile distant or 5 minutes away by auto with 100 employed in retailing activities; C_2 two miles away, or about 10 minutes away by car, with 200 retail employees; and C_3 four miles away, or 20 minutes away by car, with 400 employees in retailing.

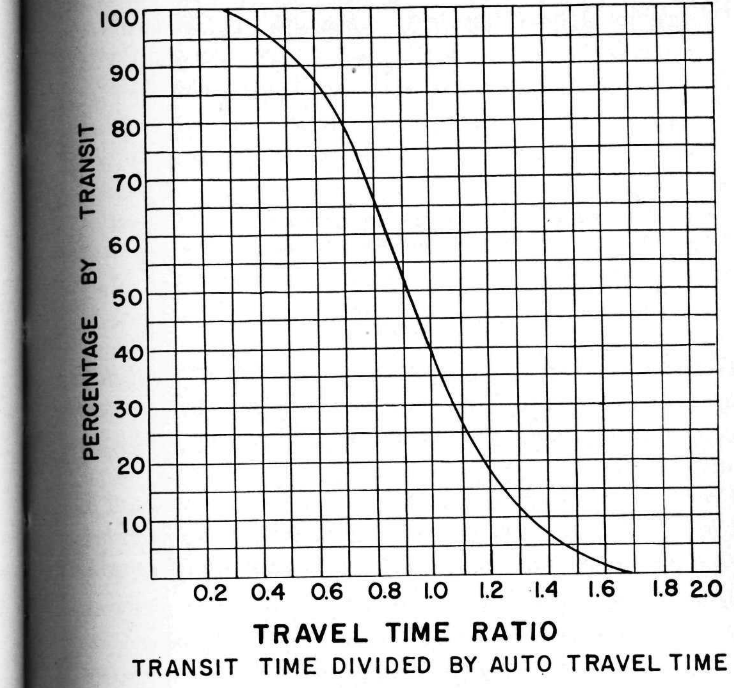


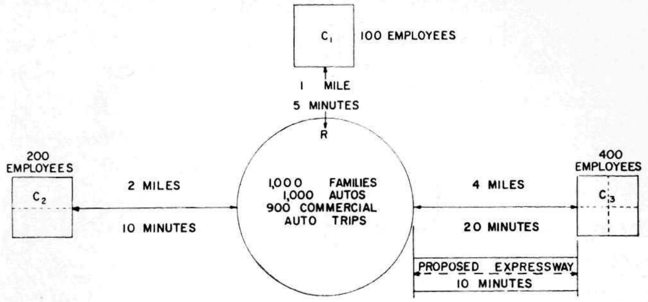
FIG. 4.—Transit Assignment Curve
(Based on Transportation Usage Study, Cook County [Illinois] Highway Department)

In line with previous discussion on commercial trip frequency, this would mean that 900 trips each day would start from the residential area R. On the basis of calculations shown in Figure 5, 513 trips would be made to C_1, 261 trips to C_2, and 126 trips to C_3.

Imagine, now, a new expressway that would enable residents to travel to C_3 in half the time, or 10 minutes. From the calculations shown, the 900 trips would be reoriented in the following manner: 360 to C_1, 180 to C_2, and 360 to C_3, resulting in 621 more vehicle miles or approximately a 40 per cent increase.

Furthermore, the new expressway would accommodate 324 additional vehicles and would increase traffic by nearly 185 per cent.

Similar reorientation in traffic movement would be observed if a new shopping center or another type of land use were established in the vicinity.



Existing "Pull"	Percentage of Total "Pull"	No. of Trips	Vehicle Miles
From $C_1 = 100 \times 4.00 = 400$	57	513	513
From $C_2 = 200 \times 1.00 = 200$	29	261	522
From $C_3 = 400 \times 0.25 = 100$	14	126	504
Total "Pull" = 500	100	900	1539
"Pull" after expressway is built			
From $C_1 = 100 \times 4.00 = 400$	40	360	360
From $C_2 = 200 \times 1.00 = 200$	20	180	360
From $C_3 = 400 \times 1.00 = 400$	40	360	1440
Total "Pull" = 800	100	900	2160

FIG. 5.—Hypothetical Example: Application of the Baltimore Traffic Model

Benefits

As in a conventional interview type of O-D study, this study permits the analysis of several transportation alternatives. The use of a model allows more flexibility and greater opportunity to evaluate these alternatives.

The role of mass transit transportation was clearly defined by studying the two alternatives mentioned previously. The survey revealed that Baltimore transit services, no matter how extensive, cannot be considered a substitute for highway improvements. Nor will they drastically reduce highway building requirements. These conclusions could not have been drawn without the use of traffic models.

This mathematical model has provided Baltimore's planning staff with a clearer conception of the city's traffic problems and, further, has helped it to envisage the effect that land use arrangements have on traffic patterns. Factually, any type of land use plan can be evaluated with such a model, and it is possible to investigate many transportation alternatives and to decide on the one making most "transportation sense."

Traffic information, developed on a directional basis, uncovered certain weaknesses in the first land use plan. It revealed that the large separation of certain residential and industrial areas placed a heavy strain on transportation facilities. City planners are currently revising land use plans to reduce these difficulties.

Other merits of the model are: the low cost of applying it (the study cost $25,000), its technical simplicity, and the limited staff that is needed. The model is by no means perfect. Although it is more highly refined than the model employed in forecasting land use, it is still in the development stage. With further experimentation and research, improvements to the model can be achieved. Despite its limitations, in its present form the model seems to be reliable, versatile, and economical.

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[5] Root-mean square error means that two thirds of the time this error will be less than specified.

ROGER L. CREIGHTON, J. DOUGLAS CARROLL, JR., and
GRAHAM S. FINNEY

Data Processing for City Planning

In city planning, data-processing machines permit the rapid handling and summarization of data in housing, renewal, land use, transportation, and basic urban research. Electronic computers, specifically, are exciting because they offer a means of solving complex city planning problems, especially in forecasting land use and travel demand.

For most planning operations punched card data processing is superior to other processes. The functions of these machines are described herein and three examples of data processing are elaborated on. In future years, planning techniques may have to be altered considerably to take advantage of the potentials of data processing.

LATELY quite a cult has grown up around the use of computers. Cults include worshippers and have their own language and a widening circle of enchanted chanters. Such terms as binary, core, magnetic drums, milli- and micro-seconds, and buffers are bandied about by the inner circle.

Naturally planners are sensitive to any good sales device, and with talk of missiles and "sputniks" it seemed wise to review computers as a planning tool at the 1958 annual meeting of the American Institute of Planners. In part, this report arises from the data-processing workshop held at that meeting.

More and more, the permanent planning agencies must collect and process survey data. Block statistics, housing, land use, traffic and population data are all commonplace in a planning operation. What is becoming increasingly necessary is the rapid manipulation of these data. This requires knowledge of the various kinds of data-processing machines and techniques. Properly used, these can save man-hours and money.

Much of the useful information of planning offices has been on maps. Recently a detailed, parcel-by-parcel enumeration of every piece of land in a city was made where the field notes were used only to color a map. Here an entire file of valuable information was lost because it is not possible to use a great volume of field sheets for analytical purposes.

The planner must become increasingly familiar with quantitative data analysis. The techniques and machines which reduce large volumes of data to the point where they are susceptible of analysis are already here. The problem is to learn how to use them. This involves both learning about the machines and learning how to handle data and how to put it in form for machine use. For the typical planning office the start will be with punched-card data-processing machinery.

On the horizon, of course, are the glamor machines. In this realm, there is promise of electronic scanning devices which can measure the area on maps according to their color.

Aerial photography is being interpreted increasingly by mechanical measurement. Kelsh plotters compute elevations which are then fed into computers to calculate the quantities of earth moving required to build new roads.

Improved traffic counters are posting data day and night, and it is possible to transmit them by short wave signals to a central data-processing point.

New mathematical models and procedures such as are described in other articles in this issue of the JOURNAL make high speed computers exciting as potential tools for manipulating large series of equations. It seems possible to simulate urban growth and urban traffic on digital or analogue computers. In this work the planner may find the mathematician a necessary member of the problem-solving team.

But all this glamor is not completely operational. The planner must first be versed in the elements of data processing. Even in punched-card manipulation there is much that is new and exciting, and the planner, with his problem-oriented approach and his natural respect for visual output, can do much to make these machines his helpful servant. The examples and discussion of data-processing machines that follow will give the interested planner some insights into these potentials.

Data Processing

Data processing consists of converting information into a form which can be handled by machinery, processing the information in a variety of ways, and finally putting it into useful form. It is comparable in some ways to the processing of a physical material: the material must be adapted so that it can be handled by machines, which then process it until it is worked into a finished product.

Two requirements must be fulfilled to justify mechanical data processing. First, there must be enough information so that the use of high-speed machinery is profitable. Second, the information must be reducible to numeric form. These requirements eliminate many types of information as not susceptible to data processing. Attention is thus focused where there are large numbers of occurrences or events (generally more than a thousand) and where the occurrences can be measured.

The city planner must remember that data-processing machinery is exact and swift, but completely unintelligent. Exactness and completeness in specifications of input and output are therefore absolutely essential. One must know *in advance* what the outcome is likely to be or else the effort will have been largely wasted.

The initial step of data processing is to get the data. Data may be obtained through a variety of surveys, such as the land use survey, the opinion survey, the origin-and-destination survey, or from secondary sources. Preplanning of data processing must start at this point and must be done carefully, even down to the design of forms.

Once obtained, data must be coded in numeric (or alphabetic) form for processing. A yes-no answer, for example, may be converted to a 1 or 2. An address may be converted to a street number followed by a number code representing a street name. Land use types may be coded 1 for residential, 2 for manufacturing, and so forth. Since most data processing works with the decimal system, the natural outline form for coding is the decimal system, with the first digit representing a major heading and succeeding digits representing subheadings. The machinery can then work with either details or major groupings.

Geographic identification will be one of the main coding problems. Data may be coded to street address and/or to block, but this is generally clumsy except in small scale situations. The organization of geographic coding for data processing is a small field in itself. One technique is the grid-coordinate system, another the polar-coordinate system. Other systems code analysis zones or census tracts within larger districts, with these arrayed in sectors and rings referenced to the central business district. Flexibility of geographic coding for summary purposes and for reassembly in different types of analysis is most important.

Once coded, data may be keypunched on cards or paper tape, or marked sensed directly on cards with the use of an electrolytic pencil. This completes the initial steps of data processing. Later steps depend upon machines whose functions must be thoroughly understood.

The Machines

There are two broad categories of machines. The first category includes the electrical accounting machine, more often known as the punched-card machine. The second category is the digital (i.e., dealing with discrete digits) computer. Digital computers assume a wide variety of forms, but essentially they operate with electrical or magnetic charges rather than with the timing and mechanical handling of cards. Computers can both process data and compute, but normally they are most efficient when used solely for computation.

Punched-card machines accomplish five principal types of functions: initial operations, processing, summarizing, calculating, and output.

The initial operations of punched-card machines include the keypunching and verifying of data from source documents. Also included are such processes as duplicating cards, gang-punching data from one set of cards to another set, reproducing cards, converting mark-sensed pencil marks into punches, and interpreting punches in cards into printed information at the top of each card.

The processing of cards is the arranging of cards in such order as will be useful for obtaining the desired results. These processes include sorting cards, selecting cards, merging (collating) cards, and matching cards.

Card machinery was developed originally as business

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machinery, and hence the accounting and summarizing abilities of these machines are highly developed. Typical machine operations include counting cards, adding up figures in a field of figures, showing totals and subtotals, and punching summary cards whenever desired so that later machine operations can deal with a reduced number of summary cards. The machines can also add a number of columns at once and balance totals against a grand total. Certain statistical counting operations can also be performed.

There are a number of computers, both electromechanical and electronic, which operate solely with card input and output. These machines will do all the jobs which the medium- and high-speed electronic computers will do, but at slower speeds.

The output of card machines takes the form eventually of a printed report, although there can be intermediate outputs in the form of cards. The printed report is prepared by the same machine which summarizes, and can be either in the form of columns of figures or (as will be illustrated by example) in the form of maps with figures giving values at certain geographic locations.

Card machines operate in the speed range of from 100 to 200 cards per minute. But this fact is not really important to the city planner. Speed from machinery is gained by providing perfect instructions which are based upon an understanding of what the machines can do. The over-all speed is then a function of machine speeds and of the time required to wire boards, to correct errors, and check results.

The cost of data processing depends upon whether a job is done with rented machinery, which is maintained on the premises, or is contracted out to a service bureau. Job for job, the service bureau will probably charge two to three times the cost of running the same job on the premises; but in the former case there is no continuing cost of overhead, maintenance, or manpower. As a rough rule of thumb, the cost of operating a self-contained accounting machinery unit (with a small calculator and a summary printer) will run from $1500 to $2000 per month, including salaries of operators. With normal overhead, electrical current, supplies, and other incidental costs thrown in, the minimum cost will run from $2000 to $3000 per month.

In contrast to data processing machinery, electronic computers are much more expensive and are not basically suited to shuffling data around. Computers are for computing; this is inherent in their design. In punchcard work, the card itself is the "memory." In computers, "memory" is in the form of magnetic charges, and these are prohibitively expensive to maintain in the machine, since the space they occupy is needed for calculation. Hence the facts must be remembered externally by recording them on cards, on paper tape, or on magnetic tape.

The genius of the computer is speed of calculation —which, incidentally, is composed only of repetitive additions and subtractions. Computers can quickly do operations which would require weeks, even on punched-card equipment. Correlation and statistical calculations are performed with ease. Matrix inversion and matrix multiplication, which is necessary for some economic forecasting, can be undertaken. Linear programming is possible.

Data are initially fed into the computer by punched cards or by punched paper tape. Therefore all the preliminary work of coding, punching, verifying, and perfecting data must be undertaken before the data are fed into the computer. Once data are in the computer, calculations and operations can be conducted with lightning rapidity. Input and output are handled at the relatively slow speed of punched-card or punched-paper-tape equipment; only in the largest machines is it worthwhile to "buffer" the input and output so that calculations can be performed at the same time or so that multiple inputs and outputs can be obtained.

Speeds and costs of work with electronic computers are extremely variable and no generalizations can be made. The apparent speed of the computer may be deceptive. The preparation of a problem for solution by a computer involves programming the instructions, debugging the instructions, checking the work, and repeating the work if mistakes have been made. All this takes time, which can be very expensive.

Three Case Studies of Data Processing Operations Related to City Planning

The CATS Land Use Survey

The Chicago Area Transportation Study (CATS) needed land use data as a basis for determining the rates of trip generation of various land uses and to provide information necessary to predict future land use patterns and, hence, future trip generation.

For these reasons a detailed land use survey was undertaken for the 1236-square-mile study area. A floor-area survey was made for 300 square miles, including the cities of Chicago, Evanston, Oak Park, Cicero, and a number of other smaller suburbs. The land use survey measured fourteen categories of uses within approximately 50,000 blocks. Eighty-eight floor-area categories were measured in buildings totaling 2.2 billion square feet. The conduct of such a land use survey without mechanical data processing was impossible within any reasonable budget.

The Study was fortunate in having a file of electric utility meter cards which identified the type of establishment purchasing current from the electric utility companies. These cards eliminated the need for field surveys and could be coupled with Sanborn maps and aerial photographs for direct measurement of land and floor area.

575	1	3	5	1	1			1	2	12	2	6	7	13	10	9	11	17		
570		4		3	4	4	9	1	1	20	6	7	3	7		11	14	10		
565		1	1	1	3	4	3	2	1	1		8	4	6	6	22	13	26		
560		3	3				9	9	27	4	7	14	8	11	10	17	18	17	1	
555		9	2			3	4	9	11	7	7	16	10	7	10	30	16	44	6	
550		3	1	5	2	5	3	17	30	13	11	9	12	10	14	24	4	15	5	
545	4	4	1	3	3	4	1	13	19	7	5	13	7	16	6	25	8	19	14	
540		1	2	1	3	6	4	6	20	18	7	36	14	21	7	30	19	24	9	4
535	1		2	6	3	8	7	9	27	30	20	12	8	28	29	55	88	21	55	5
530	3	7	8	14	2	3	2	9	11	67	6	10	13	19	36	27	4	24	1	9
525			6	28	30	19	11	7	28	10	16	4	10	26	10	26	41	9	33	11
520	2	2	13	9	4	28	6	31	53	23	30	16	9	23	41	27	40	44	14	12
515	2	2	3	2	2	8	5	15	50	16	9	10		14	14	34	29	58	39	50
510		2	1	1	3	4	5	15	93	13	6	35	14	11	16	19	19	29	54	70
505	4	20	31	16	14	7	5	7	11	9	8	22	38	14	27	29	26	31	86	154
500	5	7	9	7	7	11	13	24	42	42	27	21	31	37	33	43	63	83	153	812
495	5	9	5	5	4	6	5	14	26	13	7	20	17	12	27	38	71	149	277	1002

FIG. 1.—SECTION OF MAP PRINT-OUT. This illustration shows values printed by machine in cells which correspond to areas one half mile by one half mile. Figures to the left are Y-coordinate values.

In the floor-area survey, pertinent data from the meter cards were transferred to a marked-sensed card which was interpreted so that the address and type of establishment of each establishment was printed at the top of the card. This card was then matched with a building on the Sanborn maps; and the length, width, and number of stories of each establishment were noted on the card with an electrolytic pencil. The cards were then processed so that the pencil marks were transferred into punches and these punches were used by a card computer to compute floor areas for each building. These building floor areas (120,000 cards) were then summarized into block and quarter-square-mile floor-area summaries.

In the land-area survey, the use of land was identified by the activity of the first floor of the building on each parcel. The areas in each use in each block were recorded on a coding form which was then keypunched. These block cards were then machine summarized to quarter-square-mile grid-coordinate areas.

Both floor-area and land-area surveys were coded to a half-mile interval grid-coordinate system. The intersection of Madison and State streets was at the point $x = 500$, $y = 500$. Groups of these quarter-square-mile units made up the 582 analysis zones in the Study area. These analysis zones were numbered so that they could be grouped by districts or by rings or sectors. Summaries could thus be made successively by block, grid-coordinate, analysis zone, district, ring, and sector.

An interesting process permitted the quarter-square-mile cards to be printed on maps. The quarter-square-mile cards were arranged in order by their x-coordinates within their y-coordinates. The cards were then fed into a printer which read and remembered all the values of the cards having a single y-coordinate, and then printed the values in exact x-coordinate position across a preprinted map fed into the machine. This process was then repeated for the next y-coordinate, until a whole map had been prepared (see Figure 1). Such a map could be printed in two or three hours.

The values printed on the gridded map—in effect

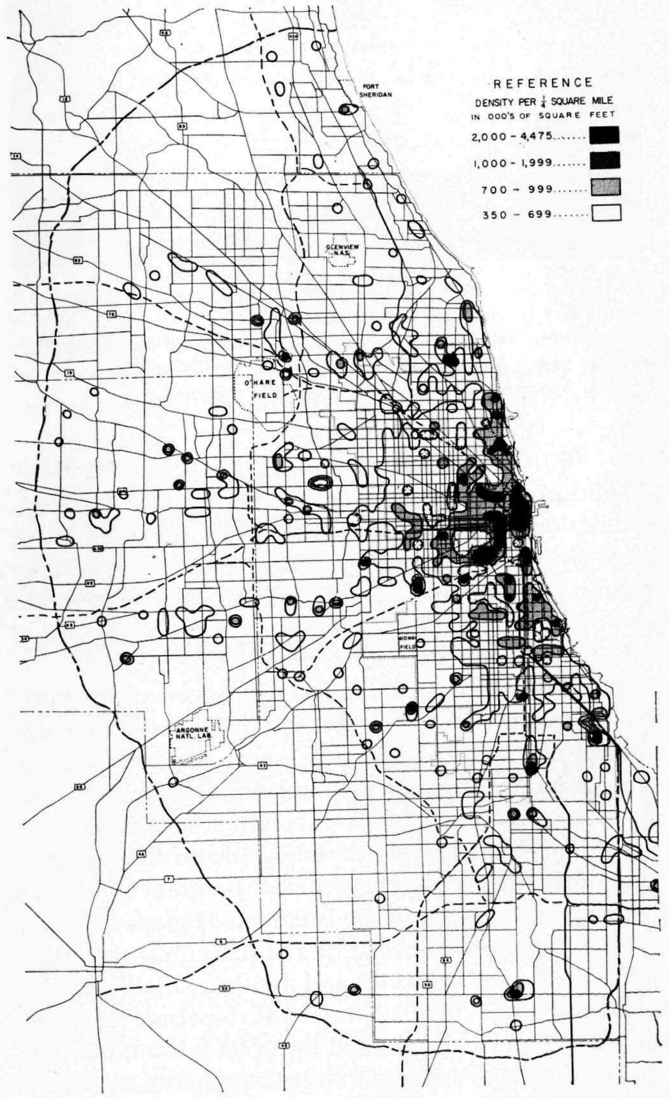

FIG. 2.—COMMERCIAL LAND IN THE CHICAGO AREA. Isolines used to connect those quarter square miles having equal amounts of commercial land area.

a geographic table—were processed by one of two methods to make the results more readable. The values could be isolined (contoured) as if they represented elevations on a topographic map, or a model could be built with the height of wooden blocks representing the values in each quarter square mile. The isoline technique is illustrated in Figure 2, showing commercial land use by a quarter square mile. The model technique is illustrated in Figure 3, showing nonresidential floor area by quarter square mile.

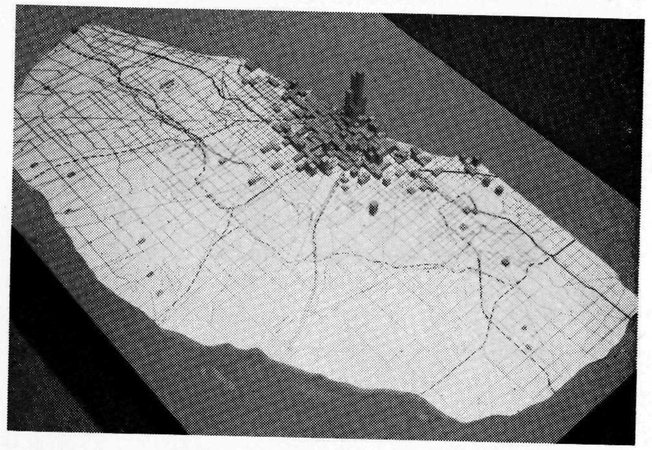

FIG. 3.—Nonresidential Floor Area by Quarter Square Mile. Wood blocks cut to fit quarter-square-mile areas have heights representing amounts of nonresidential floor area in each quarter square mile. Highest block stands for 29,679,800 square feet. Lowest block shown stands for 1,000,000 square feet.

The Portland (Maine) Central Business District Study

The preparation of comprehensive plans for Portland's downtown,[1] and for subordinate shopping areas, gave rise in the spring of 1958 to an investigation of simple mechanical data processing as a basis for the compiling of planning information and for the simple and graphic presentation of that data.

With the exception of parking information, Portland's Central Business District had never been the subject of a detailed planning study. Impetus for such a program was triggered by the customary forces: parking shortage, traffic congestion, obsolescence of physical plant, and the need to gear plans for downtown with those for the city's urban renewal program as well as with a proposed spur of the Interstate Highway System.

The amount of information required for such a project far exeeded the time and funds available to the planning staff. A request for funds to permit mechanical data processing was filled by an offer from the local office of IBM to supply at no cost the necessary punch cards, the time for punching the data, and the time and equipment required to make all the needed runs and sorts of the data.

The inventory phase of the study involved four basic sets of information or four decks of cards.

1. *A structure card* (see Figure 4 for card layouts) containing complete data as to the date, and type, and character of construction of each downtown structure, its facilities, state of maintenance, and valuation, as well as data relating to the site on which the structure was located: access, loading, on-site parking, frontages, and land valuation.

2. *An establishment card* containing a three-digit functional land use classification and detailed information regarding vacancies, employees, floor area, storage off and on site, parking for employees and customers, deliveries, and store hours.

3. *A business climate card* containing the results of nearly 1,800 personal interviews to ascertain business attitudes toward parking policy, expansion trends, and suggestions for downtown improvement. These data were deemed of special interest to the business community and their collection has helped to establish a firm liaison with many small and large entrepreneurs.

4. *A shopper's attitude card* containing the results of 750 interviews made according to a random areal sampling of the Greater Portland community. Here, the format of a study originally conducted by the Highway Research Board was adapted to local needs with the Board's permission. Interviewers for this study were personnel lent by local businessmen and trained by the planning department. A novel expression of business-city cooperation, this survey has obtained a body of hitherto uncompiled data regarding shopper attitudes and habits.

The staff is now at the outset of its analysis phase. The greater bulk of the data was compiled during the summer months by four planning interns and supplemented by members of the permanent staff of the department. It is the present intention of the department to issue a series of interrelated monographs treating the material. The tentative titles of these monographs are listed below:

1. Land use (including projected floor-area requirements by function)
2. Traffic and transportation
3. Parking
4. Market area analysis
5. Business climate
6. Shopper attitudes and habits
7. Downtown and the municipal economy
8. Downtown and the capital improvement program
9. Designs for downtown

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[1] Prepared by Graham S. Finney.

The records of all appropriate city departments together with results of more than 2,000 interviews have provided the basis for the factual information. The land use classification code was adopted from that used by CATS.

Most of the forms were developed within the planning department. Their construction was aided by a preliminary, nonmechanical inventory of one of the city's secondary shopping areas, which helped to eliminate many problems in coding. At a later stage in the program, a methodological manual may be issued for the benefit of other small cities.

Among the unique methods used in the study have been locational codes which enable the planner to pinpoint the former addresses of firms and the location of off-site storage and parking areas. The same code permits the study of entire street frontages, rather than the conventional block-by-block approach. The cards permit a structure-by-structure, floor-by-floor inventory of all space and uses. The 1958 picture is being supplemented by data from old city directories and other records.

It is estimated that approximately $4,500 of city funds, including salaries and materials, have been expended in collecting data. This figure has perhaps been matched or will be matched by the contributions made by IBM, the Chamber of Commerce, and local businessmen. Costs for analysis may amount to twice that already spent. This is an inexpensive investment in terms of the benefits to be derived, not the least of which has been the creation of a close working relationship between city hall and the business community.

The planning board's experience with data processing is still growing. The benefits already noted far outweigh any defects revealed thus far in the study. A retrospective glimpse would suggest changing the order and content of several questions on the forms. Beyond this, we have been pleased with the preparations made in advance of data collecting itself. Further work on a model central business district study using these methods should circumvent even these minor problems in other cities. In the interim, however, there should be most careful forethought before such a program is framed.

While much time has been saved, the work load in a small, active planning department makes it extremely difficult to complete so extensive a project with regular personnel at least in a relatively short period. This is particularly true when entering the analysis phase of the study. The importance of maintaining a productive pace in order to retain public interest and support has suggested the adoption of the monograph approach.

While a small price to pay for the help freely granted, the use of IBM facilities at their convenience has curbed our activities somewhat. The day of a simple data-processing installation in all city halls is thus to be looked toward eagerly! Here, for example, the application of data processing to urban renewal plan-

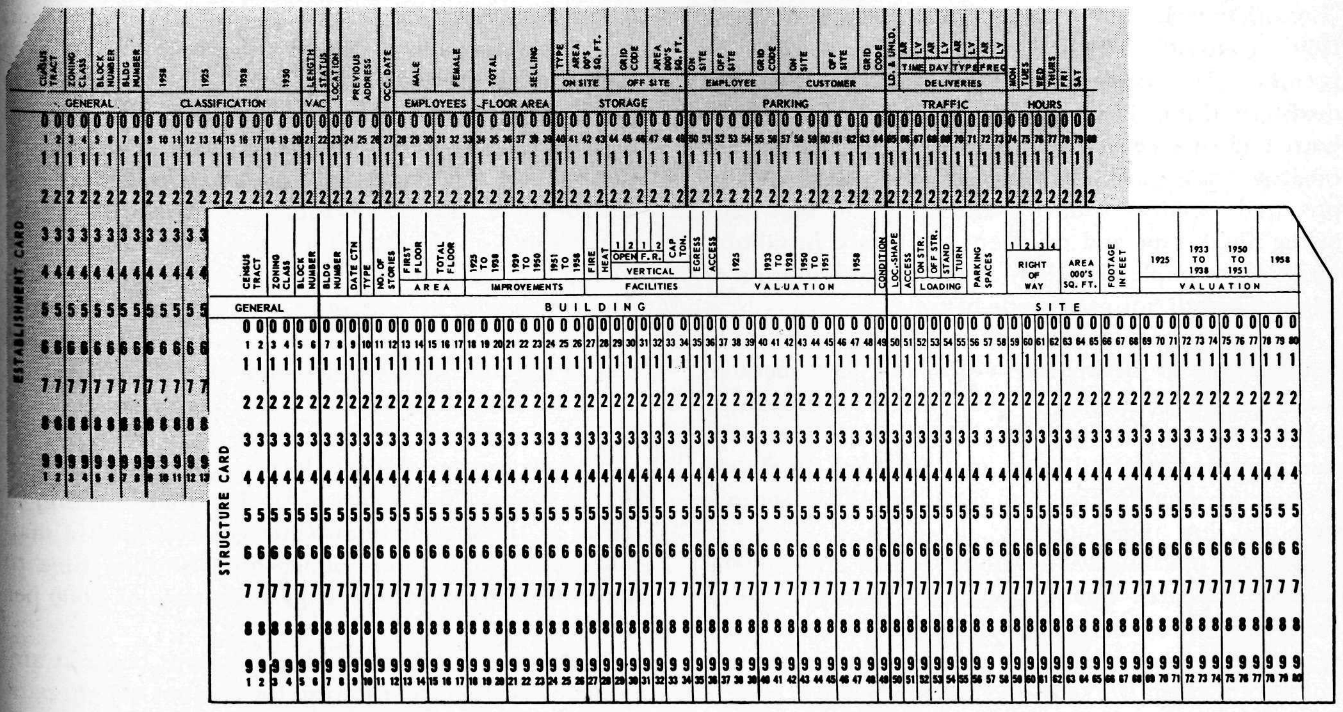

FIG. 4.—Card Layouts for Portland (Maine) Central Business District Study

ning presents a vast opportunity to simplify the task of satisfying federal requirements and permit ready use and alteration of pertinent acquisition, rehabilitation, and relocation information. This is but one example of the further application of data-processing methods. This department already has on IBM cards a full parking survey conducted by the State Highway Commission several years ago as well as a complete street inventory which is useful in capital budgeting procedure.

The CATS Travel Inventory

To prepare plans for transportation facilities, it was necessary for the Chicago Area Transportation Study to know all the related facts about travel. The origin-destination travel surveys which yielded these data produced over 150,000 completed schedules. Only mechanical means could handle these data, since each schedule might have from 100 to 300 codable pieces of information. When keypunched, these data filled over 700,000 punched cards.

The key problem then became one of digesting this vast mountain of data—making it understandable to the analyst and to the reader of a report. Several techniques were employed to do this job.

One of these techniques has already been described, that of summarizing land use data to a grid and then printing values directly on a map. The destinations of trips by rapid transit were so presented, resulting in a display showing their unique concentration in Chicago's Loop.

Another technique employed a medium-speed electronic computer which the study maintained on its premises. All trip data had been read from punched cards into this machine and "stored" on magnetic tape. Each reel of tape held the equivalent of 45,000 IBM cards. Certain short summaries of data could then be prepared rapidly by having the computer read part of the file of tape and print out the results in tabular form. An example of such a table is the distribution of trips by length, for each mode of travel.

These methods were not, however, suited to the rapid presentation of desire lines—still the best method, despite its drawbacks, for showing where all trips in an urban area are destined. Originally, desire-line maps were prepared by hand; later, methods were developed for making them by card computer, but these methods were still slow and clumsy.

A special machine was developed for the Study by the Armour Research Foundation. This machine, called the Cartographatron, is an electronic device for displaying desire lines on the face of a cathode ray tube. The Cartographatron works in the following way.

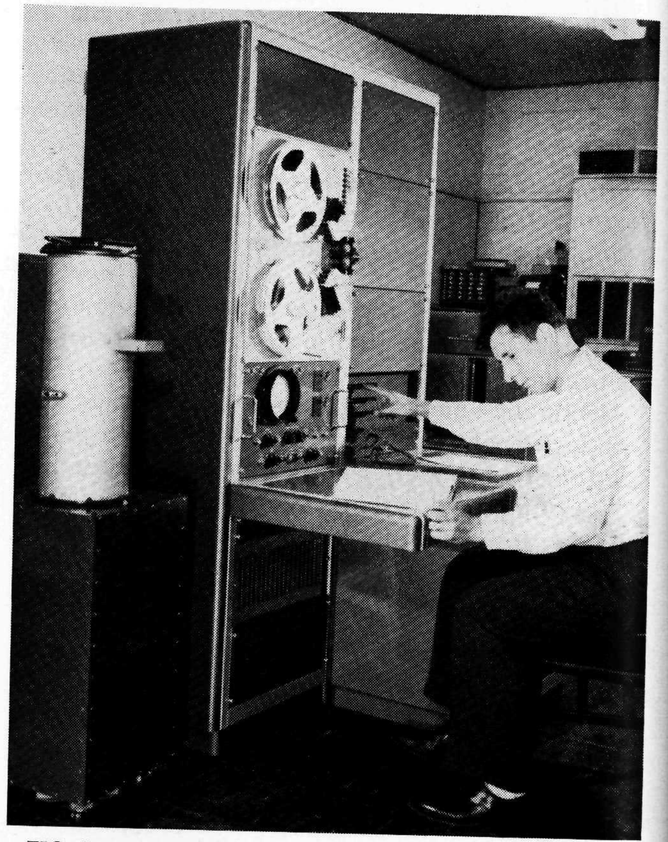

FIG. 5.—CARTOGRAPHATRON. Machine for preparing desire line maps used by the Chicago Area Transportation Study. Monitor "scope" shown under tape-reading unit. Precision tube in separate housing at left with camera mounted on top of tube face.

First, magnetic tapes are prepared on a computer. These tapes carry the *x, y* map coordinates of the origin and destination and all other pertinent data about each sample trip. These trips are "read" from the tape into the analogue system. The information is then changed to a set of electrical impulses (i.e., to analogue form). Control selectors check the type of trip to be displayed and for those trips desired for a particular map, a beam is generated on the face of a cathode ray tube from *x, y* origin to destination. This is, in effect, a desire line. A camera with its lens open is sealed in, facing the cathode ray tube. Every time a "blip" occurs on the face of the tube it is recorded on a glass plate negative. Thus trips are converted to desire lines and accumulated on a photographic emulsion.

This device can handle dots or can generate lines. Figure 6 shows the results of tracing a cross section of travel in the metropolitan Chicago area. Such a map takes about four hours of machine running time to make. It reads and traces trips at the rate of 3,600 per minute.

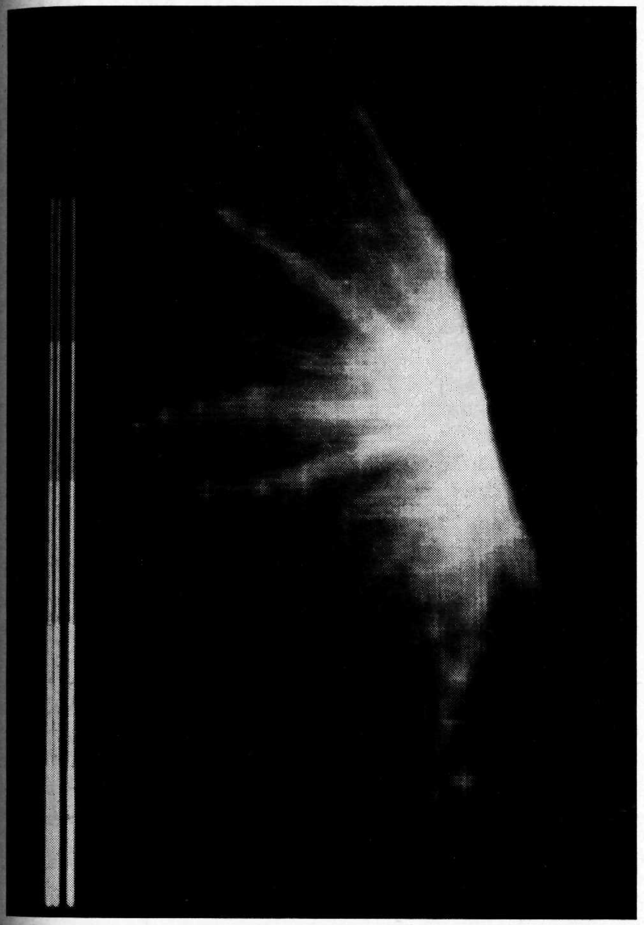

FIG. 6.—DESIRE LINE MAP OF ALL PERSON-TRIPS. This Cartographatron print shows the desire line traces of 247,700 person-trip records, representing about 9,930,000 person-trips made on an average weekday in 1956 in part of the Study Area of the Chicago Area Transportation Study. Brighter areas show a greater accumulation of desire lines. Step wedge shown at left.

If one wants to know how many trips begin at any point, a densitometer can read the amount of light passing through the negative and convert this to a numerical value which is, on the average, within about 5–10% of the true "digital" information.

This represents a tremendous advance over numbered tables. A single summary picture in accurate form is prepared very rapidly. It is possible, for example, through the use of selectors to print only a particular class of trips. One can select rapid transit riders or only those rapid transit riders going downtown from a northerly origin area, or only truck trips, or only autos traveling in excess of ten miles, or any one of a series of other types of trips. This is done by running the same tape through the reader but merely suppressing the records not wanted.

Conclusion

More and more, city planning agencies will be using data-processing machinery to reduce voluminous data to the point where they can be analyzed. Data-processing machinery can also be used to present vivid pictures of certain urban phenomena, such as land use and traffic. Without these aids, a city planning office can become swamped with unusable statistics.

With increasing use of data processing, planning can proceed with a stronger basis of factual knowledge of cities. Procedures to estimate future land use, future travel, economic growth, and other urban phenomena require accurate data. Data-processing machines can organize these data and even carry out some of the forecasting procedures. Electronic computers may be necessary for some planning operations, but for the most part simpler data processing machines can do the job.

Gradually the skills and experience which are necessary for efficient data processing will become part of the planner's tool-kit. Some of these things may find their way into planning curricula. Certainly one requirement is a stronger orientation toward data as a basis for decision making. City planners will wish to re-examine their work to see where data processing can apply and where planning techniques should change to take advantage of these new tools.

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BOOK REVIEWS

SUBURBIA, ITS PEOPLE AND THEIR POLITICS. By Robert C. Wood. Houghton Mifflin Co., Boston, 1959. 340 pp. $4.00.

I have often thought the custom of watching a squirrel dash about a spinning cage was among the more fatuous spectator sports. The squirrel, ordinarily an intelligent rodent, seems unaware that his frenetic activity leaves him exactly where he started; and for all this expenditure of energy, there is just one tired beast still in pursuit of an illusory destiny.

To Robert Wood, the suburban political ethos is somewhat like a squirrel cage, but unlike other critics of our "republics in miniature" he suggests not only freedom for the squirrel but destruction of the cage itself and elimination of the sport as a national pastime.

Professor Wood has written a brilliant book. He has insight, humor, and an objectivity particularly admirable in one who is himself a suburbanite and proud of it. He looks at the satellite community as a logical outgrowth of a deep-rooted American ideology, not merely as a phenomenon bred of the twentieth century in reaction to technocratic society and the shame of our cities. His attack focuses more on the ideology than on its manifestations. His goal is metropolitan government, but a metropolitan government founded for a different (and to this writer more valid) major purpose than any planner or municipal expert has yet proposed.

The two flaws of this book stem from Professor Wood's approach, rather than from within it. As a political analyst he pays too little attention to psychological merits in preserving the illusions he carefully dissects; and as a scholar he can claim immunity from outlining a way to achieve the ideal state he proposes. By implication, planners and opinion moulders must find the way. And for my money their first step should be to read *Suburbia, Its People and Their Politics.*

Ours is a heritage emphasizing grass-roots political activity, says Dr. Wood. This ideology stems from Aristotelian tradition plus the nature of early America and its semi-isolated, economically independent communities. While local independence was never so marked as in Europe, it was strong enough to walk hand in hand with our notions of individualism, self-determination, and unlimited opportunity to become fused in a system of uniquely American values. But mass immigration and the new technology soon changed the small communes into gigantic cities rife with corruption, living examples of weakness in the grass-roots belief. Municipal reformers then tried developing a system consonant with the ideology and the demands of urban life and made some headway, but before they succeeded "technology redeemed itself. It provided an *alternative* to urban reform."

The sleepy rural townships outside big cities became one-class suburbs overnight, hallowed their physical boundaries, and fell upon political rather than social or economic independence as the touchstone of existence.

Professor Wood summarizes what every planner knows to be the consequences of this pattern: uneven distribution of tax resources and municipal services; deterioration and specialization of central cities; rise of an interdependent metropolitan area in which separate political jurisdictions are but pieces of one pie. He underlines the growth of towns specialized by income and social class and the resulting pressures to conform.

But his major contribution is to show that the political ideology on which suburbs base their justification has clay feet. Although the small community exerts pressure for individual participation in civic affairs, by eliminating diversity and conflicting ideas from its midst, it eliminates the true meaning of individuality. "There is at work a political tendency towards homogeneity in each suburb comparable to the social and economic homogeneity." In effect, the contemporary forms of grass-roots ideology have created a schism between the two halves of our American value system. This holds true, whether the suburb be Short Hills, N.J., Levittown, N.Y., or Cicero, Ill. The sad fact is few Americans know the schism exists.

Significantly, Professor Wood never deplores suburban living per se. He is happy in Lincoln. He is for grass, trees, and two-car garages, but not as symbols of a political system. "When the fraternal order is the only order of life," he says, "it seems unsatisfactory as a way of organizing society at large and establishing a government . . . yet the concept of fraternity as a way of life is, of course, the inescapable implication of grassroots autonomy."

The analysis goes beyond this criticism of fraternity as control to reveal a serious paradox in suburban political behavior. Be it Democratic or Republican, the suburb relies on "nonpartisanship" in local affairs, and in the one-class suburb responsible two-party politics has disappeared. Nonpartisanship has, however, no effective channels for decision-making save church groups, bridge clubs, Rotaries, and the other multifarious social groupings within the town. These, contends the author, are notably inept at supplying informed political leadership. Suburban problems of water, sewage, roads, construction, etc., are complex and demand knowledgeable treatment. Since the social groupings can not supply such knowledge, and since conflicts between groups are less ones of principle than of personalities (old residents vs. new; commuters vs. stay-at-homes), actual leadership and administration often is passed on to a growing class of experts; city managers, planners, engineers, etc., whom the resident has to trust and to the rare political "wheel" for whom government is a part-time activity. The only town problems left for individual participation are taxes and land development, and here individual participation tends towards perpetuating the *status quo.* Honesty could be another issue, but Professor Wood believes that most suburban politics is clean if not efficient.

When problems become too complex, the suburbanite takes them out of the hands of one local government and gives them to another—as in special school districts—or flies in the face of everything he stands for and divorces them altogether from representative government. Creation of pseudo governments, the businesslike, independent *authorities* over essential services, in which the citizen could not have a voice even if he wished, is one of the most dangerous consequences of today's grass-roots ideology. It is evidently preferred to big-scale representative government where everyone, including the poor people of the city, has a vote.

"With the professional politicians and the party organizer banished from the scene, systematic full-time supervision and criticism of local officialdom tends to disappear.... The bureaucracy makes the key decisions by default.... In the final analysis, the suburban man may become apolitical... under these circumstances, the purest theory of democracy requires no democratic action or responsibility at all."

Advocates of metropolitan government have long said the crazy-quilt financial structure of suburban rule would one day collapse and thus key their arguments to economic necessity and efficient administration. Dr. Wood gives them cold comfort. Property taxation is outmoded, he admits, but the rich communities do quite well, thank you, and have raised ingenious controls (planners take note!) to keep out economically unproductive developments. The less fortunate towns scrape through on property taxes but depend more and more on dole from other levels of government. Twenty-seven per cent of all local revenues now come from outside jurisdictions, and in state and federal legislatures where local interests dominate, grant-in-aid activity shows no signs of lessening. Greater efficiency through larger units cannot be a compelling argument so long as the smaller units get bailed out and (by implication) the country has plenty of resources to waste. "Suburbs seem likely to pull through.... Going it alone is not only virtuous. It pays off in dollars and cents."

Robert Wood is for good government and obviously believes few suburbs have it. He is also for metropolitan government and believes the planners and others are selling it the wrong way. They should not try to soft-soap the public by advocating metropolitan federation as a sop to grass-roots ideology. It fools no one. They should attack the ideology itself and contend that only through big municipal government, where the one-class suburb becomes a neighborhood competing and cooperating with other neighborhoods for control, will truly democratic government be restored. This means the return of two-party politics to local affairs; the recognition that other groups, races, and classes, should be heeded; and the liberation of the individual citizen from cords of homogeneity. That Professor Wood's solution would hold new problems is obvious to him as well as to the reader, but it is difficult to conceive of another course, particularly with the recent proofs from Philadelphia and New Haven that partisan politics and conflicting minorities pay off in civic conscience and physical rebirth.

We created our bigness, the author says, and we should not shun it. We should accept it as a new challenge in keeping with others the country has met on its road to greatness.

The author's role as analyst allows him to avoid detailing a program to achieve metropolitan government on this basis. I submit that an attack on the grass-roots ideology is essential, but will meet resistance simply because the organization man, aware of his immersion in groups and processes much bigger than he, finds refuge in illusions about the small suburb. Perhaps he cannot really exert himself, steer the town along a proper course, become an effective public force, but he thinks he can within the existing framework. Often the illusion of reality is harder to puncture than reality itself. I also suggest that the arguments for financial rationality and efficient use of resources will eventually, if not now, have telling effects, simply because we will find ourselves with fewer resources to waste.

Suburbia, Its People and Their Politics holds many lessons for planners, one of which is the obvious futility in developing long-range plans for short-sighted localities. The moral of this story may be found in one of Professor Wood's most quotable passages:

Those who wish to rebuild the American city, who protest the shapeless urban sprawl, who find some value in the organizational skills of modern society must recognize the potency of the [grass-roots] ideology. Until these beliefs have been accommodated, reform will not come in the metropolitan areas nor will men buckle down to the task of directing, in a manner consonant with freedom, the great political and social organizations on which the nation's strength depends. A theory of community and a theory of local government are at odds with the prerequisites of contemporary life, and, so far, theory has been the crucial force that preserves the suburb. There is no economic reason for its existence, and there is no technological basis for its support. There is only the stubborn conviction of the majority of suburbanites that it ought to exist, even though it plays havoc with both the life and government of our urban age.

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"THE FEDERAL HIGHWAY PROGRAM AND ITS SIGNIFICANCE TO REAL ESTATE." By Henry J. Kaltenbach. *The Appraisal Journal,* Chicago, July 1956.

"RESIDENCES AND FREEWAYS." By John F. Kelly. *The Appraisal Journal,* Chicago, October 1957.

The authors of these two papers are to be congratulated for the clear presentation of their subjects. They indicate the growing awareness on the part of those who are directly concerned with the national highway program of the effect of real estate upon the program and of the effects of the program on real estate.

The cost of rights-of-way in urban areas was estimated at the beginning of the program at 31 per cent of the construction costs of urban highways. There are indications that the actual cost is likely to be considerably higher.

The advance acquisition of property long before construction begins is suggested as a means of keeping down the acquisition cost. *Special Report No. 27,* of the Highway Research Board, on "Acquisition of Land for Future Highway Use," issued subsequently, advocates strongly such advance acquisition. However, so far, only a few states have been able to provide "revolving funds" for this purpose. Besides the problem of providing the necessary large funds, there is a problem of the interim use of the property. The same problem of tying up large sums of money stands in the way of the so-called "land bank" plan in connection with urban renewal. This plan has been proposed for reducing the cost of urban renewal through advance purchasing of property, clearing it, and keeping the land until the proper opportunity to resell or reuse it.

The "short term housing" plan now under consideration by several federal agencies and favored by leaders of housing and urban renewal groups, makes the advance acquisition of land for urban renewal and, in some instances, for highways, possible.

Interim use is to be for "short term housing" under the following plan. Property, in the blighted areas which are slated for ultimate clearance, would be acquired, the worst structures demolished and the rest improved. This improvement would mean cleaning up the backyards by removing shacks, broken fencing, and rubbish piles; and keeping them clean while bringing the dwelling to livable condition by temporary repairs (perhaps requiring heavy maintenance cost but no capital expenditures).

Besides the quick improvement of housing conditions of a great many families at a nominal public cost, the plan makes it possible to buy property cheaper through unhurried negotiations and to sell it for redevelopment at the most favorable real estate market conditions.

Thus there would be a very large saving in the urban renewal costs as well as in the urban highway rights-of-way where they are located in obsolete areas. Other benefits would include easing of relocation which plagues all of the urban programs, and integration of these programs resulting in more orderly operations.

The principal finding of the painstaking survey of the effect of freeways on adjacent residences is that the people accept with a slight depreciation in value the houses adjoining the freeways. This should not be taken by highway and land planners to mean that the safeguards provided for the protection of the homes is sufficient.

The findings are based upon the data for "mass housing," serving less discriminating people than those living on isolated sites. These people, who selected their isolated homesites in part, possibly, because of the environment, were excluded from the survey for various reasons including the highly emotional state of some of them.

Irrespective of the immediate effect on resale value of the property, almost half of the owners would not buy a home, next time, backing on a freeway, largely because of noise, fumes, and vibration.

As time goes on and more people learn by their own experience or by the experience of others what the results of living next to a freeway mean, the effect on the resale values may be much greater.

The survey brought out some other significant information. At least one owner spent hundreds of dollars for a concrete block wall for privacy of his rear yard next to the freeway. It is doubtful if this added to the resale value of his property as compared with similar property without a concrete wall a block away from the freeway.

Houses on the lots backing on a freeway but with a greater distance from the freeway than other houses, had not shown decrease in resale value.

Thus it appears that deeper lots with room for effective screening by heavy planting may be more effective than local access roads which (according to the survey) do not do much good as buffers.

It is to be hoped that the environmental effects of a modern highway upon people living near it, will be studied as thoroughly as the economic impact.

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METROPOLITAN GROWTH AND THE CONVERSION OF LAND TO NON-AGRICULTURAL USES. By Donald J. Bogue. Scripps Foundation for Research in Population Problems, Miami University and University of Chicago, 1956. 33 pp. 60 cents.

This booklet contains less than 15 pages of text and yet the story it tells reflects the husbandry of the white man in his use of the 1.9 billion acres of land in the pre-Alaska United States. Professor Bogue throws light on the question: What is the growth of our cities doing to the supply of land in the country? His sources are primarily three: (1) H. H. Wooten, "Major Uses of Land in the United States," and the supplement of this monograph published by the U. S. Department of Agriculture, 1953; (2) the Census of Agriculture 1949 as related to the Population Census of 1950; and (3) a special survey of land conversion in California completed in 1956 by the Soil Conservation Service.

There is an abundance of figures of percentages, tables, and formulas in this publication and a number are worth remembering. For example, the figures on crop lands for the country as a whole have remained relatively constant at roughly 20 per cent of the total from 1920 to the latest data of 1950. This equilibrium results from the fact that extensive reclamation programs have been compensating for the loss of farmlands due to urbanization and other causes. The best estimates place a million acres of rural land, mostly good crop land, as being used up annually by urban and related uses. It is doubtful that reclamation can continue to offset this loss much longer.

On the basis of increased population alone, a "new" family of four people now absorbs two thirds to one acre of farm land. The author admits that this is high because it is related only to population growth whereas actually it reflects also decentralization from the congested centers of our cities. This decentralization is largely a by-product of the automotive age; before 1920 the rate of conversion by population growth was much less.

Whenever one reads of a cold snap that freezes citrus fruit in Florida and the winter vegetables in Louisiana, the housewife as well as the student of population should be concerned over the future of such areas as the Imperial Valley in California where year-around production is high and crop failures are rare. Professor Bogue points out that 16 per cent of all cultivable land in this state had been lost to farming by 1956. Less land means less freeze-free fruit and higher prices at the supermarket.

The author is cautious as to predictions and consequences of the findings in his report. His "Summary and Implications" deserves more attention from the reader than does the end of the text on page 19. He spends much of his text and tables on data for the Standard Metropolitan Areas and then assumes, because some 80 per cent of our population growth occurs within SMA's, that this is a "highly efficient course in the special location of [our] population increase." To this reviewer, many of our SMA's look like shotgun marriages of less-than-well-coordinated blobs of built-up areas. However, it is pleasing to be told that we are doing only moderate damage to productive agricultural areas.

This report gives the barest reference to the trends and potentials of zoning as a tool to divert urban growth away from prime farming lands. More on this would have been welcome. The author is aware that there is inadequate source material focused on the subject at hand. In spite of these limitations the reader will agree that these data introduce a challenging subject.

But the reviewer's mind kept wandering away from the tables of thousands of acres and percentages of change. What happened to the habits of the people as the former farm communities became suburban to the cities? Did the fruit trees or corn fields or the Saturday square dances have any lasting influence on the newcomers? Are the suburban kids better educated than their predecessor country cousins? Will they become better men and women? Whatever the answers, there are still broad areas of good land being put to good use in the raising of corn and kids. For this we may be thankful.

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METROPOLITAN COMMUNITIES: A BIBLIOGRAPHY. By Government Affairs Foundation, Inc., Public Administration Service, Chicago, 1957. 392 pp. $10.00.

The Government Affairs Foundation has published this extensive bibliography as a development of its own file of published, and some unpublished, material concerned with metropolitan areas. It is not prepared for planners but contains much material of value, as few in our profession are not connected with elements of a metropolitan region.

Chapters I through III are concerned with the functions, problems, organization and politics in metropolitan areas. These make up 80 per cent of the book. In these chapters the references on housing and renewal, subdivision control, and zoning cover 33 pages. The material has been selected carefully; more important references are indicated and the majority is annotated. Of particular value is the reference to magazine and unpublished material. A section under "Planning" gives major reports for particular communities by states. Foreign items are few and generally limited to Canada and England.

Chapters IV through VI cover social structure, population, and the metropolitan economy. This material covers a look at the city and its people as a whole, including such central functions as downtown business districts. Planners will wish to look through these references with care as there is much to be gained here in terms of fitting the tools of the trade to the character and needs of our communities.

In selecting material, the emphasis is on the conclusions, thought, and processes used rather than in seeking out the latest published data. It is a pleasure to see the names of Thomas Adams, Ebenezer Howard, and Sir Raymond Unwin listed among the authors whose works are valid today.

R.S.R.

CORRECTION

The JOURNAL regrets that two errors occurred in the review by Eliahu Romanoff of *Sociology of Urbanization: A Study in Rurban Society* by T. Earl Sullenger, appearing on page 52 of the February 1959 issue (Vol. 25, No. 1). Second paragraph, line 1: *read* urban *for* rurban. Third paragraph, line 5: *read* sources *for* resources.

To appear in the August 1959 issue

PLANNING ORGANIZATION AND ACTIVITIES WITHIN URBAN GOVERNMENT
Henry Fagin

COMPREHENSIVE PLANNING AS A FIELD OF STUDY
Melville C. Branch

CITIZENS AND PROFESSIONALS RECONSIDER THE NEIGHBORHOOD
Howard W. Hallman

THE MASTER PLAN: AN INQUIRY IN DIALOGUE FORM
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PAGES FROM PLANNERS' NOTEBOOKS: NOTES ON INDUSTRIAL SITE PLANNING
S. B. Zisman

The Cumulative and Annotated Index covering the years 1925-1958 is now available. Single copy: $5.00